Water-Quality Parameters and Benthic Algal Communities at Selected Streams in Minnesota, August 2000—Study Design, Methods, and Data

By K.E. Lee

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Charles G. Groat, Director

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For additional information write to:
U.S. Geological Survey
District Chief
2280 Woodale Drive
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CONVERSION FACTORS AND ABBREVIATIONS

Multiply metric unit	By	To obtain inch-pound unit
inches (in.)	2.54	centimeters
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
degrees Fahrenheit (°F)	(Temp. ^oF - 32) / 1.8	degrees Celsius (°C)

Concentrations are given milligrams per milliliter (mg/L). A milligram is one thousandth of a gram. Electrical conductivity is measured as specific electrical conductance in units of microsiemens per centimeter (μS/cm) at 25 degrees Celsius.

Water-Quality Parameters and Benthic Algal Communities at Selected Streams in Minnesota, August 2000—Study Design, Methods, and Data

By Kathy E. Lee

ABSTRACT

Water-quality measurements and benthic algal samples were measured or collected from select Minnesota streams as part of a multiagency (Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, U.S. Environmental Protection Agency, and U.S. Geological Survey) study. The goal of the multiagency study was to identify quantifiable thresholds of water-quality impairment and establish quantifiable indicators of nutrient enrichment for medium to high-order streams.

This report describes the study design, sampling methods, and summarizes the physical, chemical, and benthic algal data for a component of the multiagency study that was designed to document diurnal water-quality measurements (specific conductance, pH, water temperature, and dissolved oxygen), benthic algal community composition and chlorophyll-*a* content, and primary productivity at 12 stream sites on 6 streams in Minnesota during August 2000. Specific conductance, pH, water temperature, dissolved oxygen concentrations and percent dissolved oxygen saturation measurements were made with submersible data recorders at 30 minute intervals for a period of 3-6 days during August 2000. Benthic algae collected from wood and rock substrate were identified and enumerated. Biovolume (volume of algal cells per unit area), density (number of cells per unit area), and chlorophyll-*a* content from benthic algae were determined. These data can be used as part of the multiagency study to develop an understanding of the relations among nutrient concentrations, algal abundance, algal community composition, and primary production and respiration processes in rivers of differing ecoregions in Minnesota.

INTRODUCTION

The presence of contaminants, and physical or chemical degradation affects 36 percent of surveyed river miles in the United States (U.S. Environmental Protection Agency,1998). Historically, water-resource management efforts focused on point sources of contaminants such as industrial and wastewater treatment discharges. The focus has shifted more recently to the influence of nonpoint source runoff on water quality (Boyd, 2000). Nonpoint source contaminants such as nutrients (nitrogen and phosphorus) enter streams through runoff from the land surface during snow-melt, spring and summer precipitation, from ground-water discharge, or from tile drains and storm sewers (Osborne and Wiley, 1988; Wiley and others, 1990). Nutrients are essential for animal and plant growth; however, elevated nutrient concentrations are potentially toxic to humans and wildlife and can stimulate excessive algal and plant growth (Wetzel, 1983).

The U.S. Environmental Protection Agency (USEPA) total maximum daily load (TMDL) rules are part of the Clean Water Act section 303(d) requiring each state to identify streams that are not in compliance with multiple water quality standards including nutrient concentrations (U.S. Environmental Protection Agency, 1998). Both abiotic and biotic factors and interactions between them influence nutrient concentrations, and a greater understanding of these factors and interactions is necessary to develop locally-relevant TMDLs.

Abiotic factors influencing water chemistry include climate, geology, land use and land cover, soil type, topography, and hydrologic characteristics. Biotic factors including instream plant and animal metabolism also influence water chemistry. The most influential biotic factor affecting nutrient concentrations and other constituents in streams is algal community uptake and metabolism (Stumm and Morgan, 1996). Algal communities in streams are comprised of phytoplankton (algae entrained in water column) and benthic algae that reside on submerged substrates including woody debris (epidendiric), rock (epilithic), and macrophytes (epiphytic). Benthic algae include

attached forms and phytoplankton that have settled onto the bottom of streams in quiescent areas.

Benthic algal photosynthesis and respiration processes influence nutrient flux (Newbold and others, 1982; Stumm and Morgan, 1996) and other water-quality parameters such as specific conductance, pH, dissolved oxygen and carbon dioxide. During photosynthesis, algae utilize energy from sunlight, take in nutrients and carbon to produce carbohydrates (needed in algal cell growth), and produce oxygen as characterized by this stoichiometry (Stumm and Morgan, 1996):

$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122\ H_2O + 18\ H^+$
(+ Trace Elements and Energy) $\longleftrightarrow$
$C_{106}H_{263}O_{110}N_{16}P_1 + 138O_2$ sunlight
(algal protoplasm)

Changes in pH, dissolved oxygen, and nutrient concentrations occur during this process. Dissolved oxygen and pH concentrations increase, and dissolved nutrient concentrations decrease as algae increase photosynthetic activity during the day. The uptake of carbon dioxide during daylight accompanied by the uptake of nitrate (NO_3^-) or phosphate (HPO_4^-) and H^+ ions results in a pH increase due to the remaining OH^- ions. Dissolved oxygen and pH decrease during the night as photosynthesis ceases and aquatic animals continue to consume oxygen and respire. The reduced dissolved oxygen concentrations and pH at night are also augmented by microbial bacterial decomposition of biota to NO_3^-. Biological oxygen demand (BOD) is a measurement of the amount of oxygen required to stabilize the demands for oxygen during the microbial decomposition of organic matter (Reid and Wood, 1976).

In addition to their roles in chemical modulation, algae provide a source of oxygen and carbon for primary and secondary consumers such as aquatic macroinvertebrates and fish. Primary productivity (the rate of formation of organic material over some time period) is an indicator of the health of a stream (Wetzel, 1983) because oxygen and carbon sources form the base of the food chain in aquatic systems. Benthic algae are important primary producers in streams (Stevenson and others, 1996) and may be the primary source in mid-size streams (Vanote and others, 1980).

Establishment of water-quality standards for nutrients has not historically been based on the complex interactions of abiotic and biotic factors. The information generated in this and concurrent studies will provide an opportunity to develop statistical relations between chemical factors (nutrient concentrations) and biological factors (primary production processes or algal community composition) that can be used by managers in stream-water-quality-criteria development.

Purpose and Scope

The report describes the study design, methods, and provides selected water-quality parameters and benthic algal data for 12 sites located on six Minnesota streams sampled during August 2000. The purposes of the study were to document specific conductance, pH, water temperature, dissolved oxygen (DO), benthic algal abundance, community composition, and chlorophyll-*a* content, and to provide estimates of net primary productivity and respiration at each site. This study is one component of a multiagency (Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, U.S. Environmental Protection Agency, and U.S. Geological Survey) study designed to develop an understanding of the relations among nutrient concentrations, algal abundance, algal composition, and primary production and respiration processes in rivers of differing ecoregions in Minnesota. Ecoregions were used as the major spatial strata because they are areas with common ecological settings that have relatively homogenous features including climate, geology, land use and land cover, soil type, and physiography (Fandrei and others, 1988; Omernik and Gallant, 1988). The goal of the multiagency study is to identify quantifiable thresholds of water-quality impairment and establish quantifiable indicators of nutrient enrichment for medium to high-order streams.

STUDY DESIGN AND METHODS

Site selection criteria included drainage area, ecoregion type, and presence of a streamflow gaging station. The 12 sites on six rivers selected for this study had drainage areas greater than 1,000 mi^2. These sites were located within four different ecoregions at or near U.S. Geological Survey (USGS) or other streamflow gaging stations (fig. 1, table 1, at the back of the report). Rivers that were representative of each ecoregion were selected. Two sites were sampled on each river to allow upstream and downstream comparisons of nutrient flux in a concurrent study. Each site has a designated site identifier. The site identifier is comprised of two or three letters corresponding to the river name followed by numbers that correspond to the river mile near the site location. For example, the Crow Wing River near Nimrod, Minnesota (CWR-72.3) is located 72.3 miles upstream of the confluence of the Crow Wing and the Mississippi Rivers.

August was selected as the time frame for this study because the objective was to determine water quality and algal characteristics during low to medium flow and to minimize the likelihood of runoff. Precipitation generally is less frequent during late summer and rainfall events usually produce less runoff, because

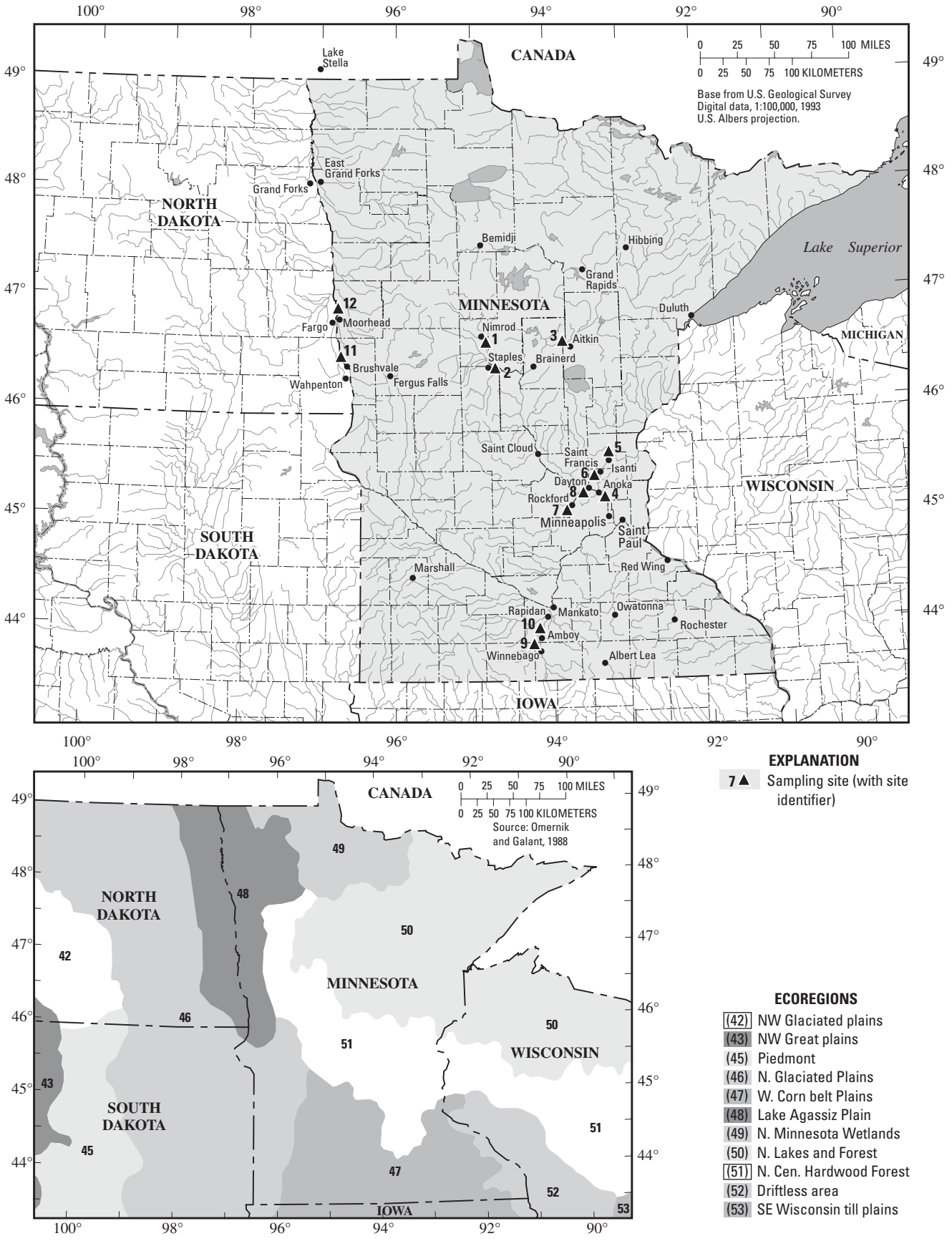

Figure 1. The location of sampling sites where diurnal water-quality measurements and benthic algae samples were collected during August 2000, and ecoregions in the study area.

of reduced soil-moisture and extensive vegetative cover on cropland areas. In an extensive study area, such as Minnesota, the amount of time required to adequately sample selected streams increases the probability that streamflow will be unsteady in some streams because of precipitation-induced runoff.

Precipitation Data

Daily precipitation data were obtained to provide an environmental context for diurnal water-quality measurements and benthic algal data. Daily precipitation amounts for August 2000 were obtained from the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu). Daily rainfall data were obtained for the weather station closest to the stream sampling site.

Hydrologic Data

Daily-mean streamflow (the mean discharge for a particular day) for June through August 2000 was obtained for USGS stream gages that were located near sampling sites (table 1). The daily-mean streamflow provides information about near-term conditions that may influence physical, chemical and biological characteristics. The long term mean-daily streamflow (mean for a particular day over the period of record) was also computed for each site and provides a benchmark to determine if streamflows during the study period were generally higher or lower than average conditions. These hydrologic data were obtained from the USGS National Water Information System's Automated Data Processing System.

Diurnal Water-Quality Measurements

Measurements of specific conductance, pH, water temperature, and DO were recorded at 30 minute intervals over a period of 3-6 days using submersible data recorders (HydoLab Data Sonde units). The probes were positioned in the euphotic zone in an area of streamflow of at least 1 ft^3/s. The probes were calibrated according to manufacturers specifications before installation at a site and following retrieval. New batteries and DO sensor membranes were installed prior to each deployment.

Stream Productivity and Respiration Estimates

Stream productivity and respiration were estimated using DO concentrations over diurnal periods (table 2, at the back of the report). Chlorophyll-*a* content in benthic algae was also measured as an alternate measure of primary production. Net productivity and respiration estimates were quantified according to Sorrenson and others (1999). Briefly, productivity estimates were determined by calculating the slope of the DO concentrations between 10 am and 3 pm. This time period was used because the rapid rates of change in DO were linear. The estimates define the net rate of oxygen accrual in milligrams of oxygen per Liter per hour (mg O_2/L/hr), which is equivalent to grams of O_2 per cubic meter per hour (g O_2/m^3/hr). Net community respiration was quantified by calculating the slope of the DO concentrations between midnight and 6 a.m. Estimates of productivity and respiration do not account for rates of oxygen diffusion that are a function of water temperature and the difference in oxygen saturation between water and air (Odum, 1956).

Benthic Algae Collection and Identification

Benthic algae were collected from each site during the period of diurnal water-quality measurements. Site conditions were characterized at the time of benthic algae sample collection (table 2). Benthic algae were collected from both wood (epidendric) and rock (epilithic) substrate at each site and processed separately. Benthic algae samples were collected in accordance with the USGS National Water Quality-Assessment Program (NAWQA) algal sampling protocols (Porter and others, 1993).

Epidendric samples were collected from submerged woody debris that was in the euphotic zone of the stream. Epidendric samples were collected from 10 locations in each stream reach. Snags were gently removed from the water to minimize disturbance of the algal community; a 3–4 inch cylindrical section was cut from each snag with lopping shears; and the snag sections were retained in a plastic bag prior to processing. After algae were removed from the snag sections, the length and diameter of each section was measured, and the surface area of each snag segment was calculated.

Epilithic samples were collected from submerged rocks located in the euphotic zone. Approximately 10 different rocks, which were carefully removed and placed in a container with benthic algal growth facing up. After algae were removed from each rock a foil template was created to cover the section of the rock covered with algae. This foil template was retained and measured to determine surface area.

Samples were processed similarly as described below. Algae were removed from each snag section or rock using a stiff-bristled brush and de-ionized water from a rinse bottle. The algal suspension from each sample (epilithic and epidendric samples were processed separately) was washed into a small, plastic processing pan. Samples were processed until about 50 to 100 mL of water had accumulated in the processing pan. The combined algal-water suspension

was homogenized for approximately 30 seconds. The homogenate was split into subsamples for determinations of chlorophyll-*a* (5mL), and identification (60 mL). The homogenate from one sample (Mississippi River near Anoka, Minnesota) was split into three portions to determine variability in algal samples.

Chlorophyll-*a* samples were filtered through a 0.47 mm glass fiber filter with 5 pounds of pressure per square inch. The filter was placed in foil inside of a petri dish and placed on dry ice prior to analysis at the Minnesota Department of Health Laboratory. Taxonomic samples were placed in a glass bottle with 1 percent glutaraldehyde as a preservative and kept in a refrigerated low light environment prior to shipment to Phycotech in St. Joseph, Michigan for analyses. Identification of algal taxa were accomplished by Phycotech personnel using methods modified from Crumpton (1987). HPMA (2-hydroxypropyl methacrylate) was used in sample mounting which provides an optically clear background while permanently infiltrating and preserving the sample for archival purposes.

HYDROLOGIC CHARACTERIZATION

The hydrologic conditions during June and July 2000 prior to sampling were characterized by variable stream discharge in response to storm events. Daily-mean stream discharges during June and July 2000 were characterized by one or more storm events of varying magnitudes (fig.2).

Hydrologic conditions during the August sampling period were stable and streamflows were below the long-term mean flows at most sites except at the Red River of the North sampling locations where the flow was low and stable, but was greater than the long-term mean streamflow. Precipitation events of approximately 0.5 inches occurred during sampling collection periods at the following sites: Crow Wing River near Nimrod and Staples (CWR-72.3 and 35.5, respectively); Mississippi River near Aitkin (UM-872); Crow River at Rockford (CR-23); Blue Earth River near Winnebago and Amboy (BE-73.2 and 54, respectively); and Red River near Brushvale and Moorhead (RED-536 and 452, respectively).

PARAMETERS WATER QUALITY

Table 3, at the back of the report, shows summary statistics for diurnal measurements of specific conductance, pH, water temperature, dissolved oxygen and pecent oxygen saturation at each site. Figures 3-14 show specific conductance, pH, water temperature and dissolved oxygen for each site. The y-axis scale for a selected constituent may not be similar in figures 3-14 due to differences in data magnitude which would obscure the patterns of the water-quality parameters within each site.

In general, dissolved oxygen concentrations, dissolved oxygen percent saturation, pH and temperature values increased, and specific conductance values decreased during daylight hours. These trends were reversed during nighttime period. Dissolved oxygen concentrations went below the state standard of 5.0 mg/L at the Mississippi River at Anoka (fig. 6).

The pH values for the Crow Wing River near Staples (fig. 4) is missing due to probe malfunction. Specific conductance at the Red River near Brushvale (fig. 13) is problematic due to the non-gradual change in specific conductance after the rain storm on August 16th. An independent measure of the specific conductance on August 15th was similar to that recorded by the submersible data sonde and the post deployment-calibration check of the sonde was acceptable. It is not possible to determine if the abrupt change in specific conductance was a result of runoff from precipitation or probe malfunction.

Primary Production and Respiration

Net community primary production and respiration estimates are shown in table 4, at the back of the report. Potential factors influencing rates of primary production and respiration include the density of benthic algae, aquatic macrophytes, abundance of phytoplankton, solar intensity/cloud cover, precipitation, water temperature, hydrologic characteristics, the density of aquatic insects that graze on algae, microbial community composition, and density of aquatic organisms utilizing dissolved oxygen. Net community primary production varied from 0.03 to 1.10 $g/O_2/m^3/hr$ among all streams. Net community respiration estimates varied from 0 to 1.09 $g/O_2/m^3/hr$. Chlorophyll-*a* content varied from 2.1 to 150 mg/m^2 among all samples (table 5, at the back of the report). Net community primary production and respiration rates and chlorophyll-a contents observed for streams in this study were similar to those observed for 72 agricultural streams in the upper midwest (Sorenson and others, 1999).

Benthic Algae

Community composition is represented by both biovolume (volume of algal cells per unit area) and density (number of cells per unit area) of taxa. Biovolume is closely linked with observed thickness of algae on a substrate. Bivolume provides an estimate of biomass and represents taxa shifts well when the size of algae are variable (Stevenson and others, 1996). Density estimates generally have less variability than biovolume, but taxa shifts may be obscured when cell sizes are variable. Table 6, at the back

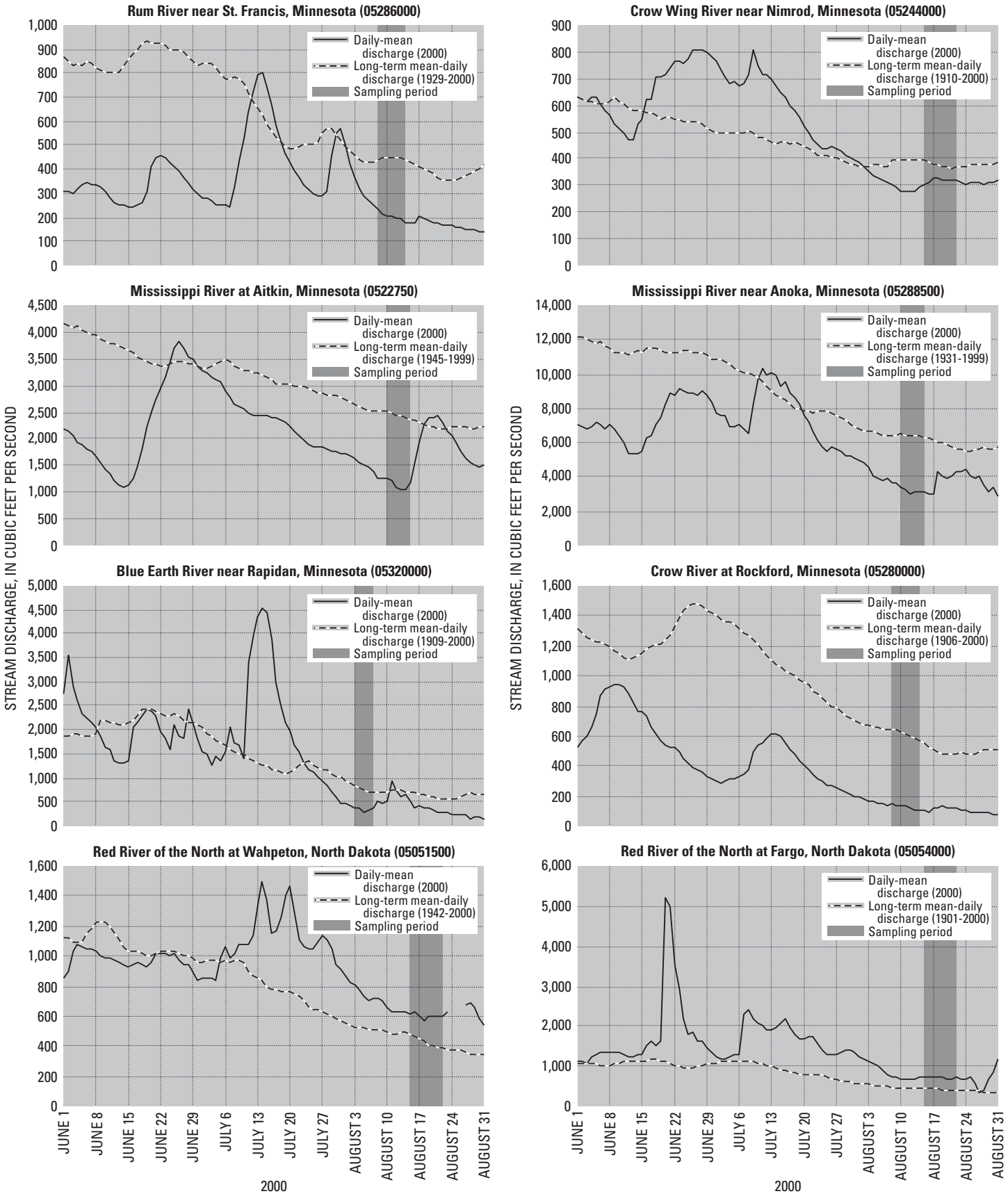

Figure 2. Daily-mean stream discharge during 2000, and long-term mean-daily stream discharge during June, July, and August at U.S. Geological Survey gaging stations near sampling sites. USGS stream gaging station names and numbers are shown on each figure. (See Table 2 for information that corresponds USGS gaging station to sampling site.)

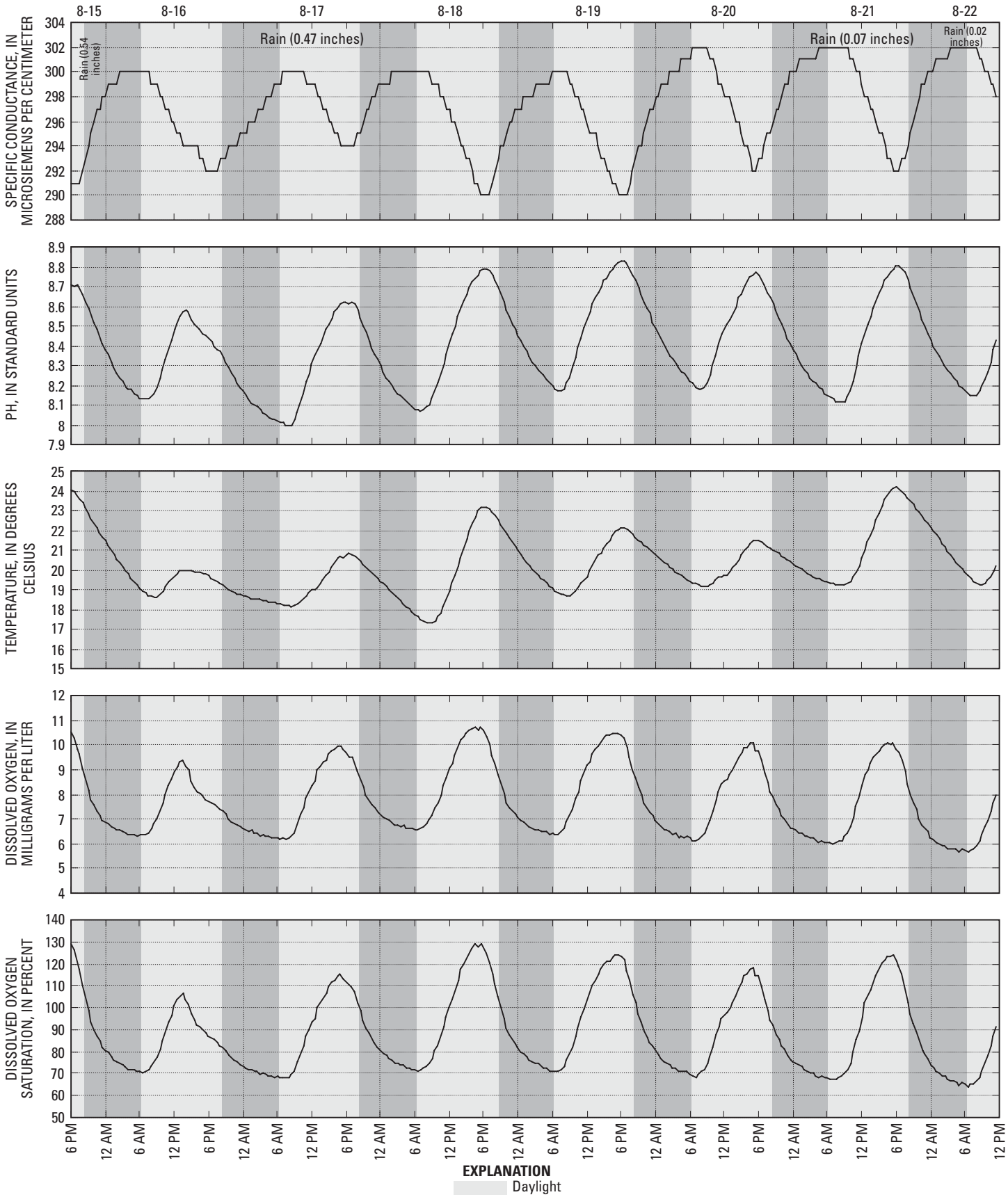

Figure 3. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow Wing River near Nimrod, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

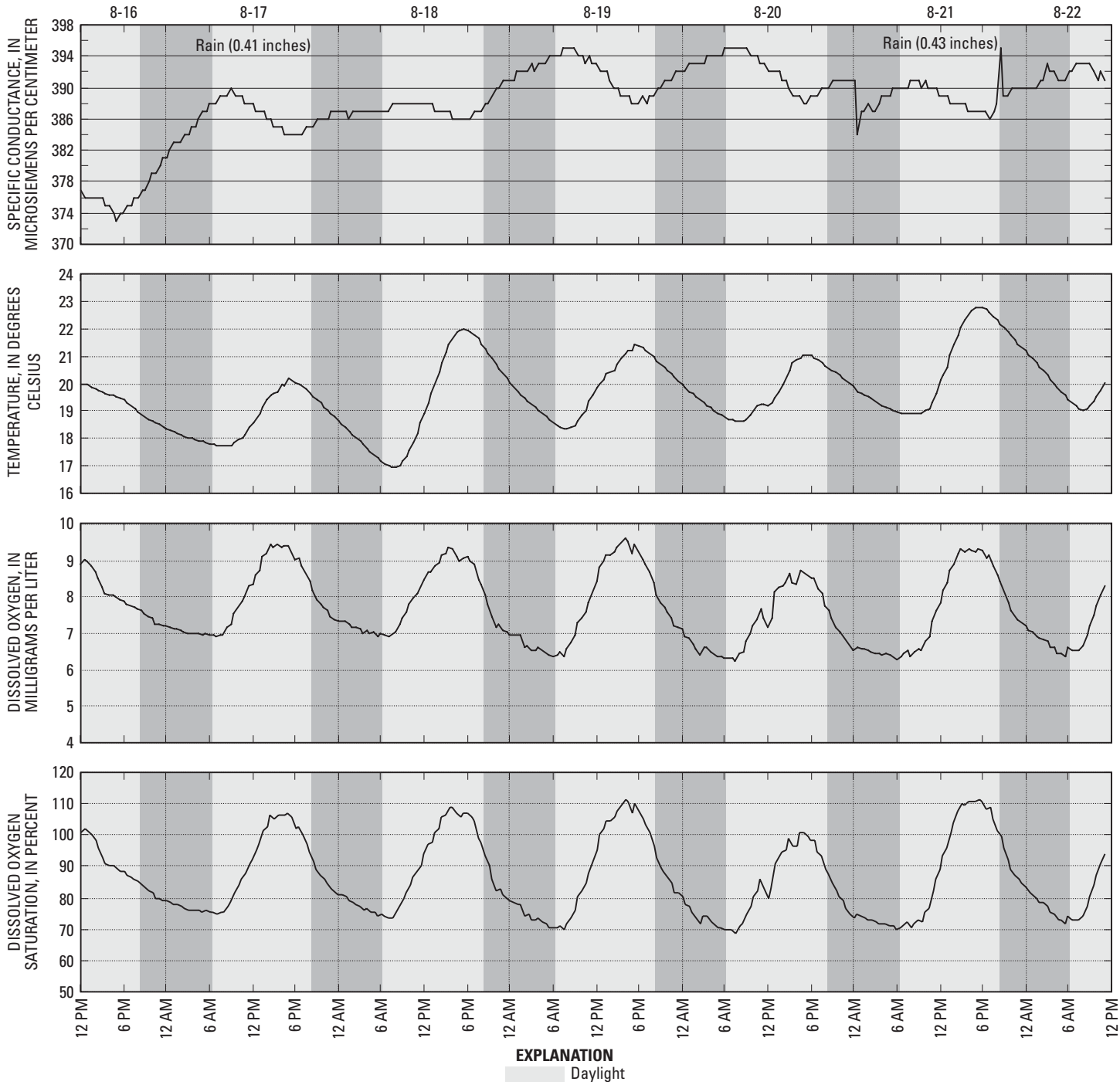

Figure 4. Specific conductance, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow Wing River near Staples, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 16-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu). pH values are missing due to equipment malfunction.)

of the report, shows the total biovolume and density for each site. Tables 7-10, at the back of the report, show the relative biovolume and density of benthic algae on rock and wood substrates. There were five major divisions and 154 algal taxa found among all sites. The composition of the community varied between substrate types and among all sites. Biovolume and density varied among sites as well as the number and types of taxa.

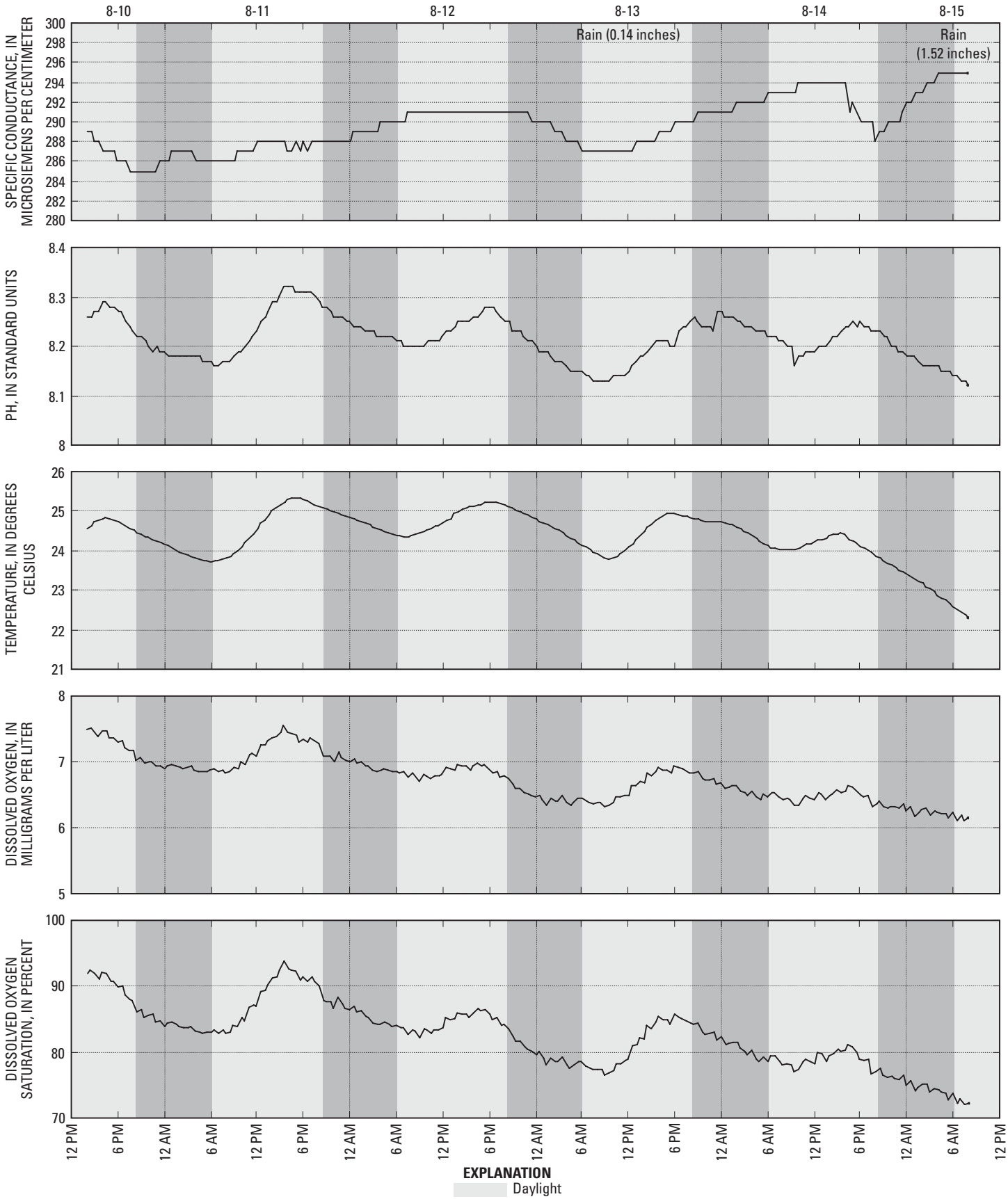

Figure 5. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Mississippi River near Aitkin, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 10-15, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

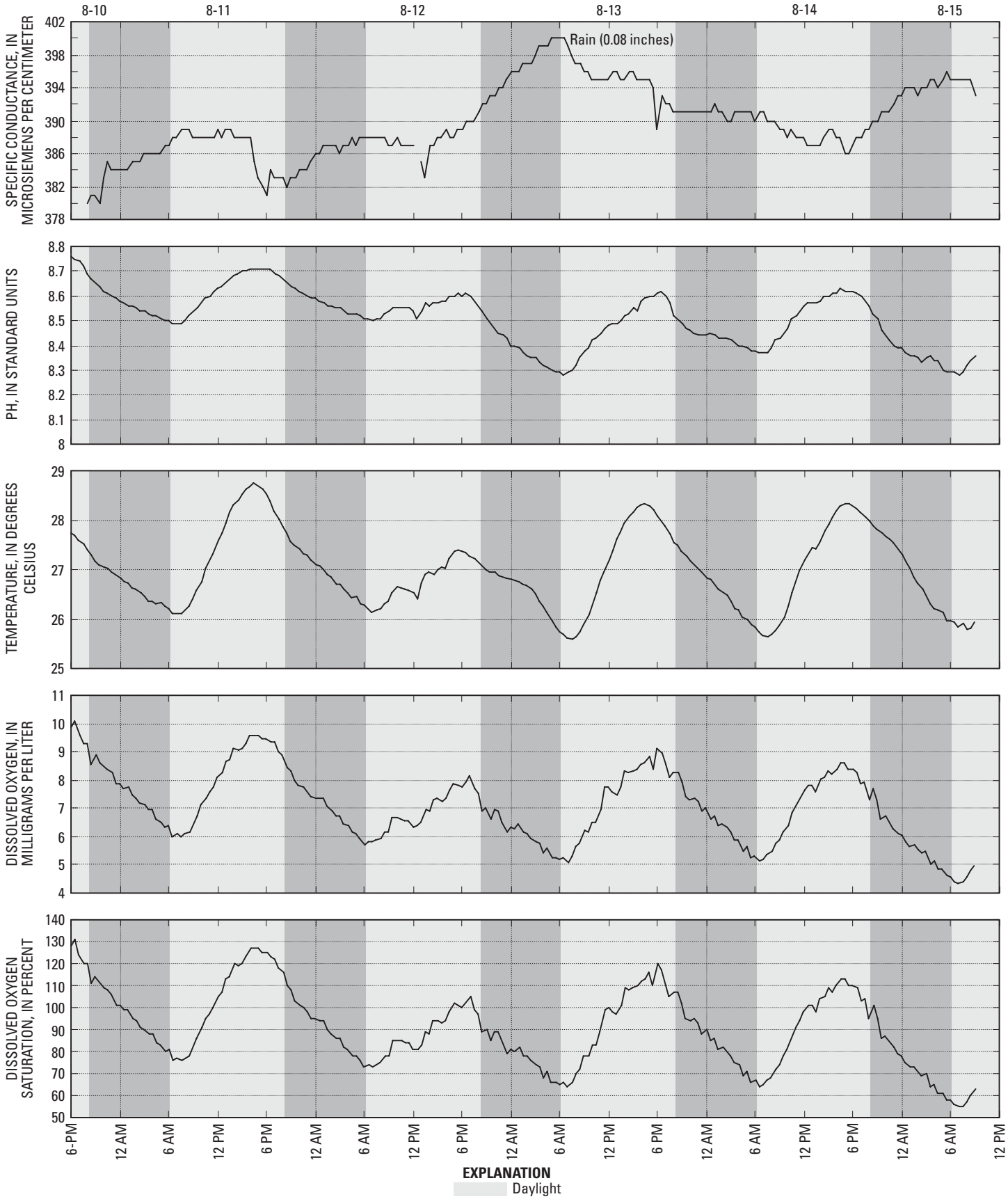

Figure 6. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Mississippi River near Anoka, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 10-15, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

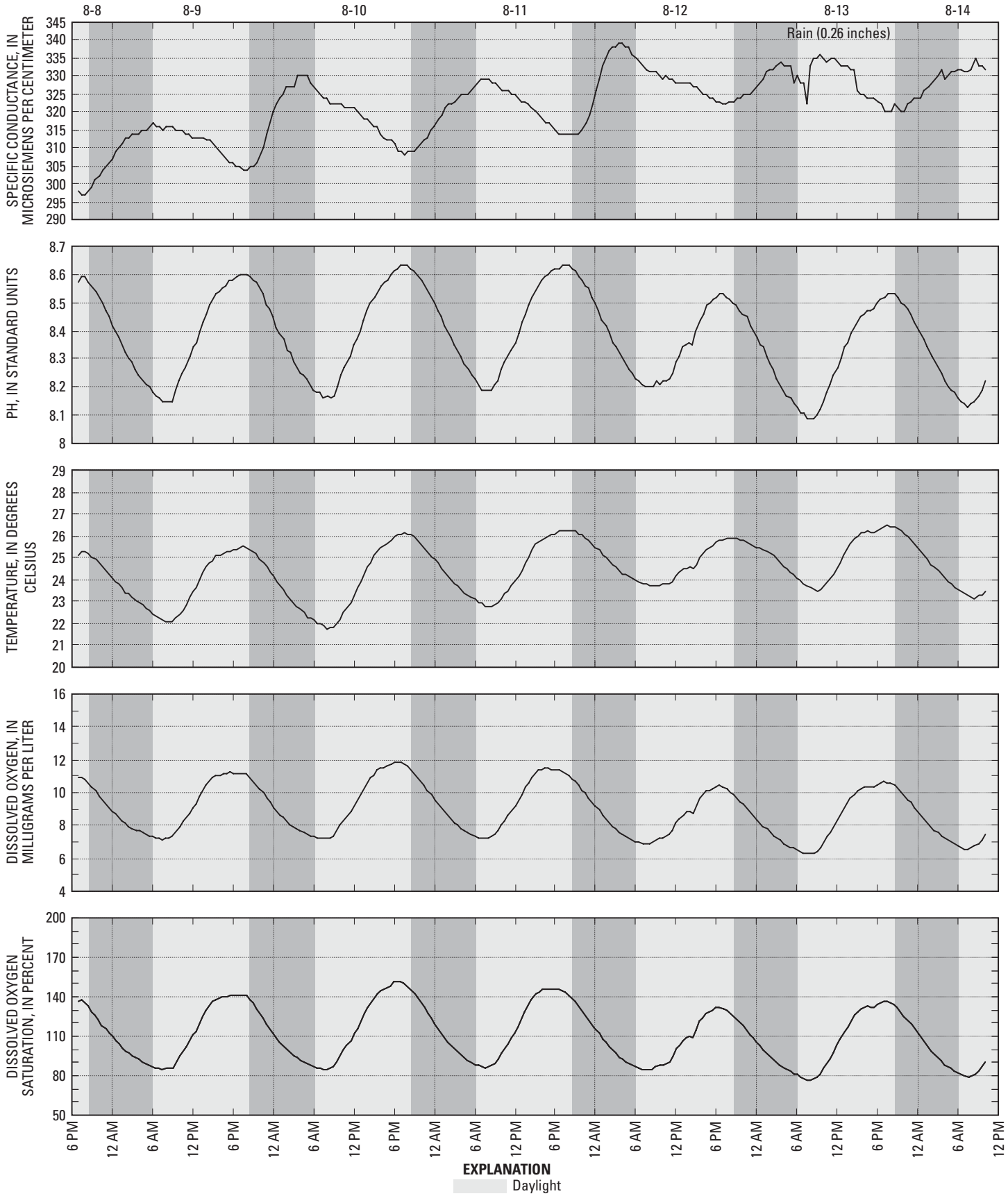

Figure 7. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Rum River near Isanti, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

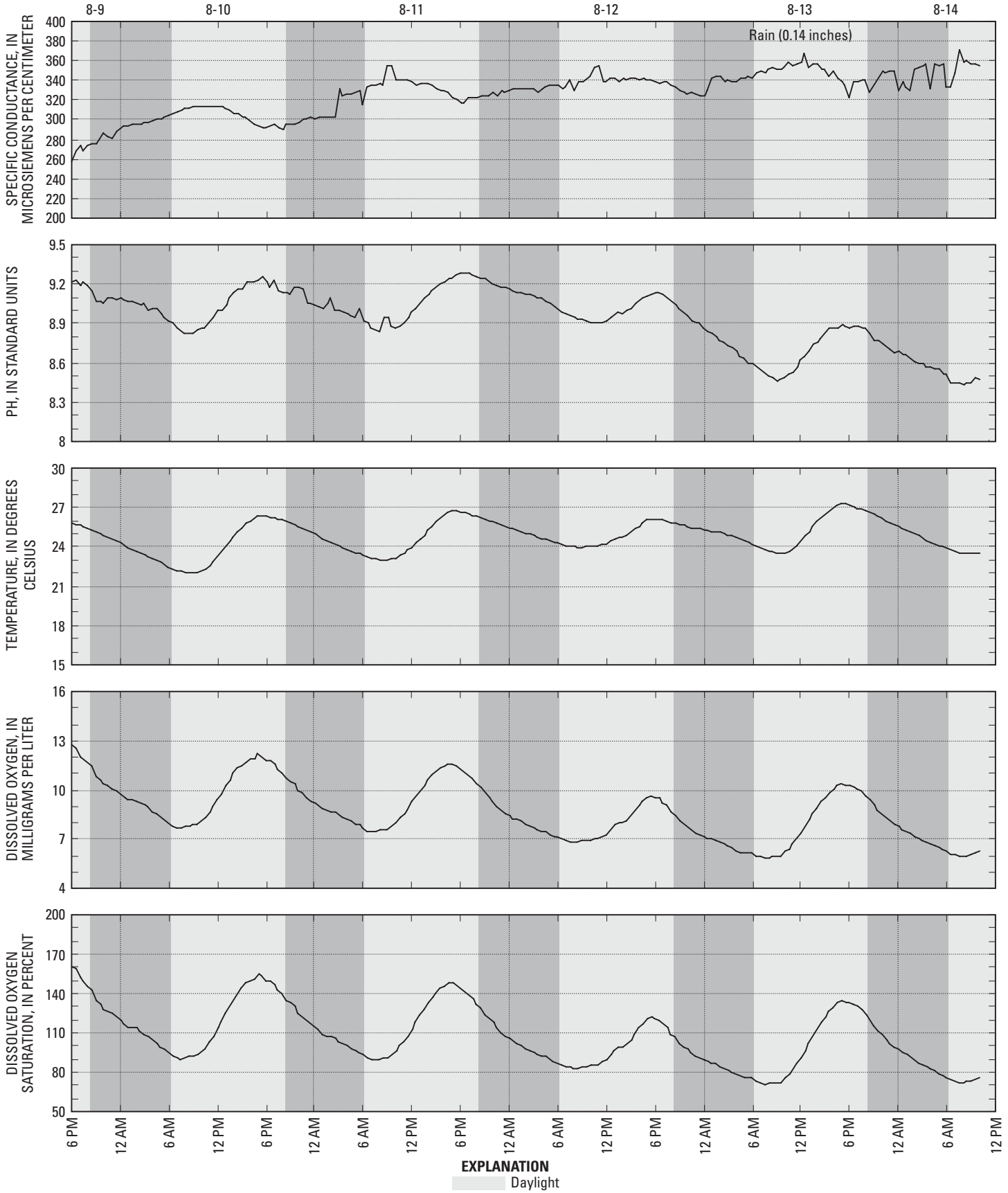

Figure 8. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Rum River near St. Francis, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 9-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

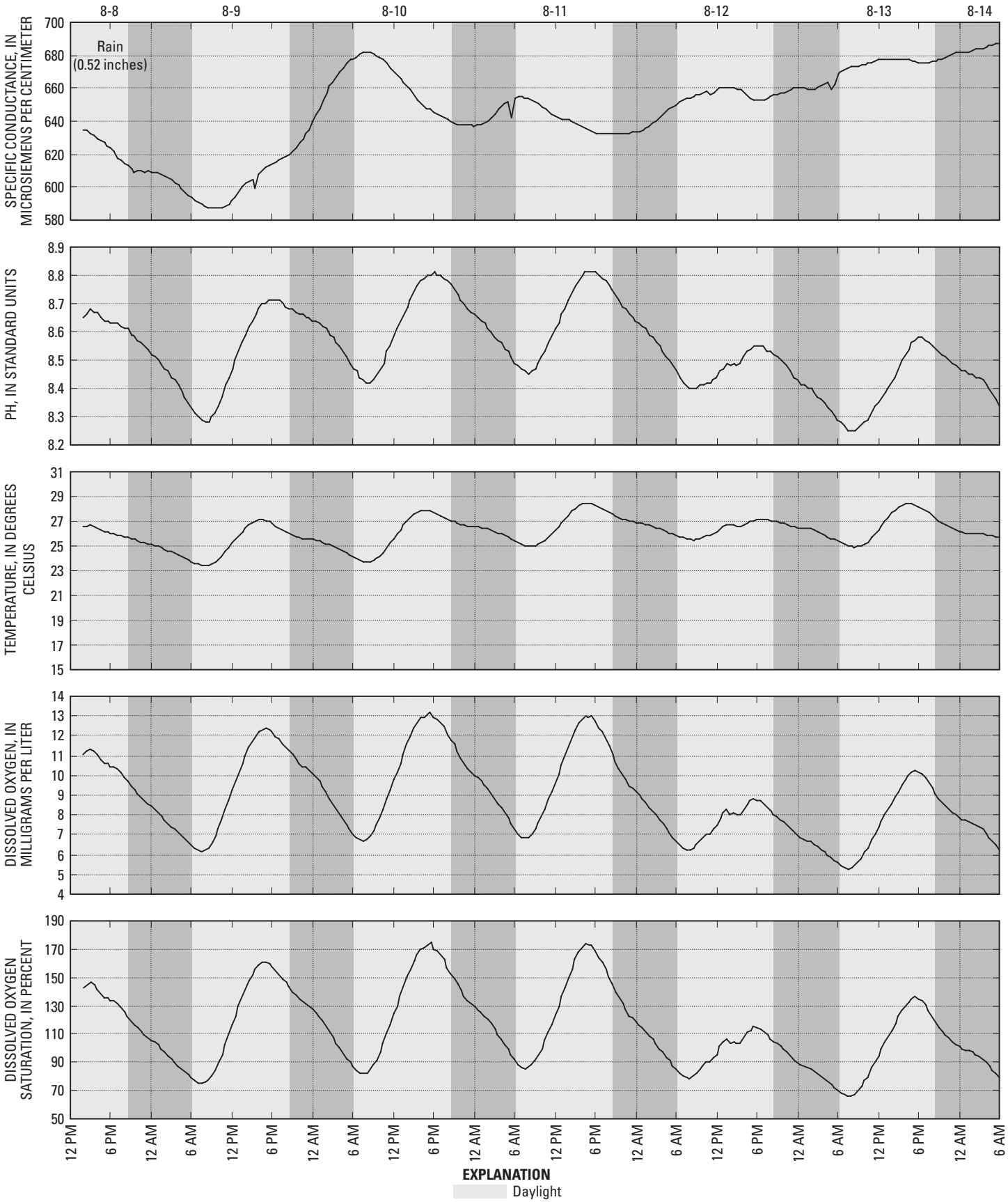

Figure 9. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow River near Rockford, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

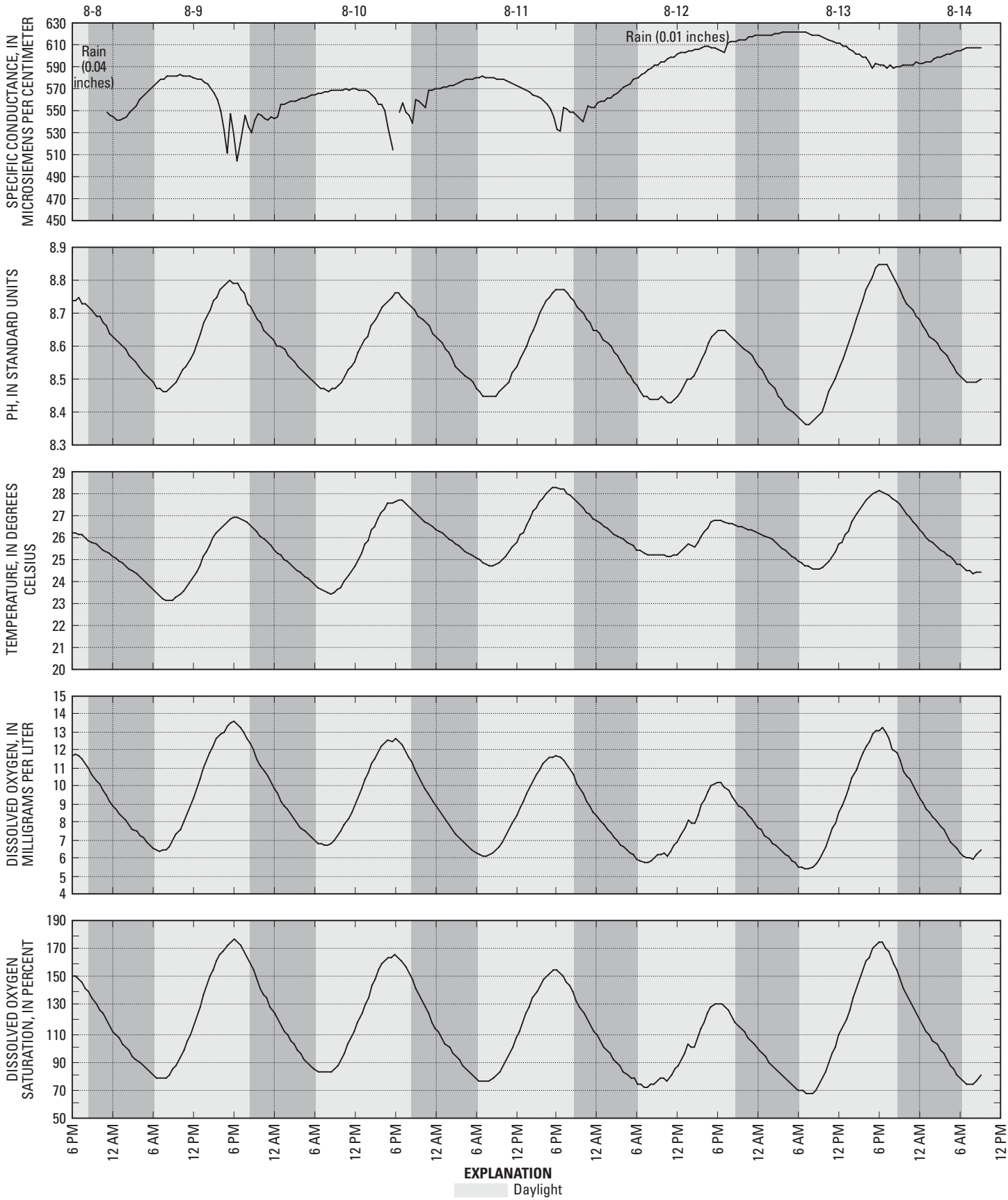

Figure 10. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Crow River near Dayton, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 8-14, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

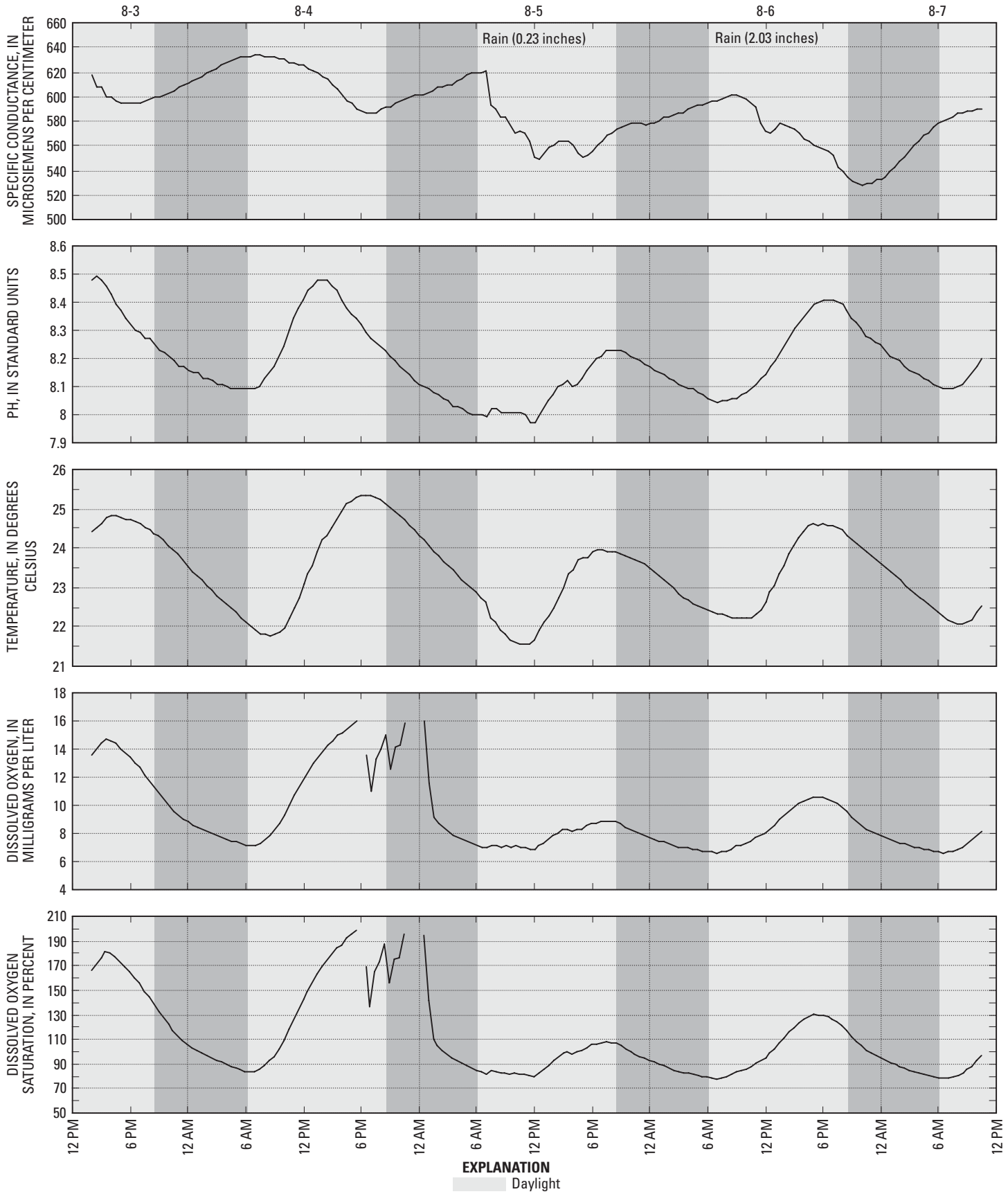

Figure 11. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Blue Earth River near Winnebago, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 3-7, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

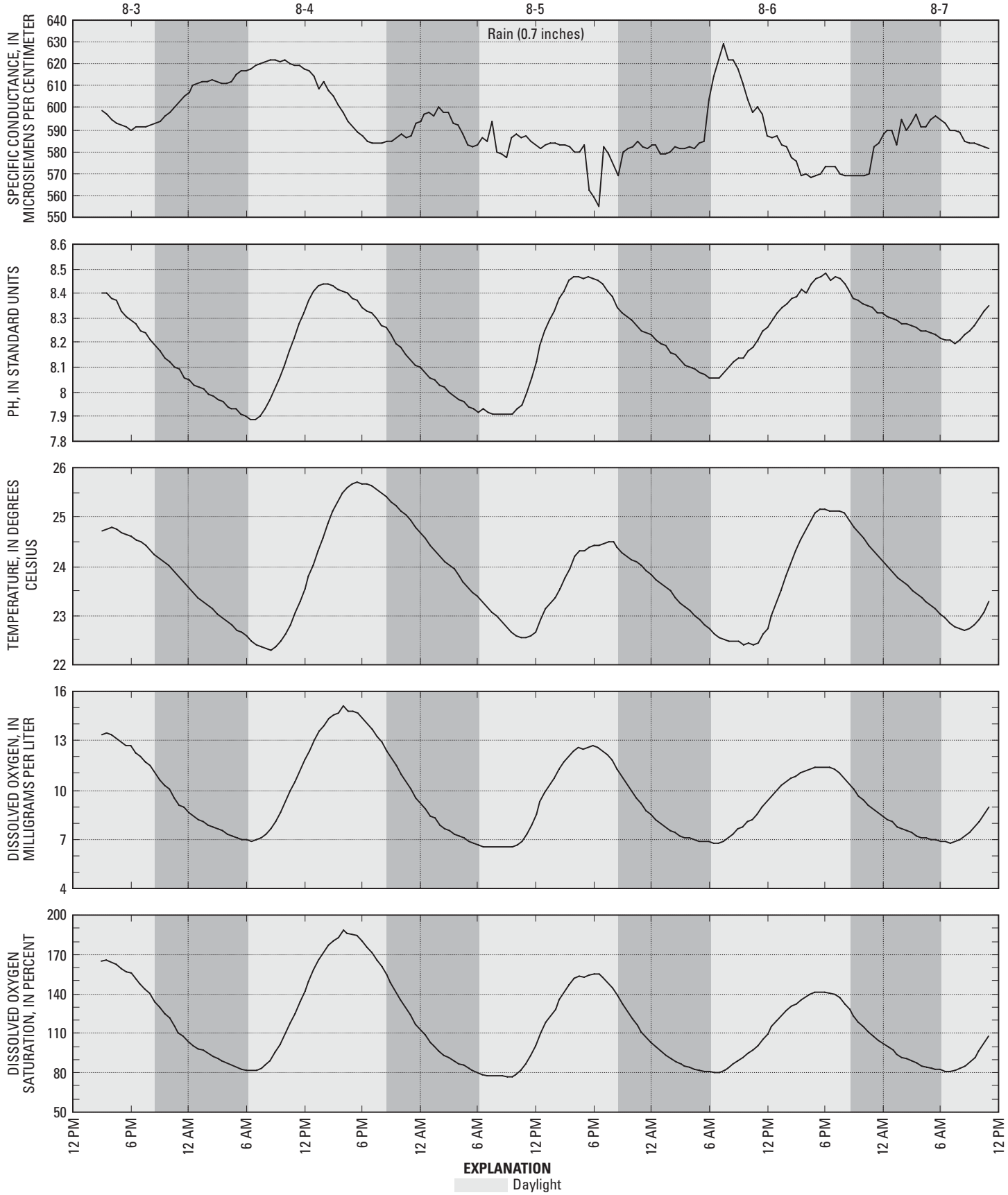

Figure 12. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Blue Earth River near Amboy, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 3-7, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

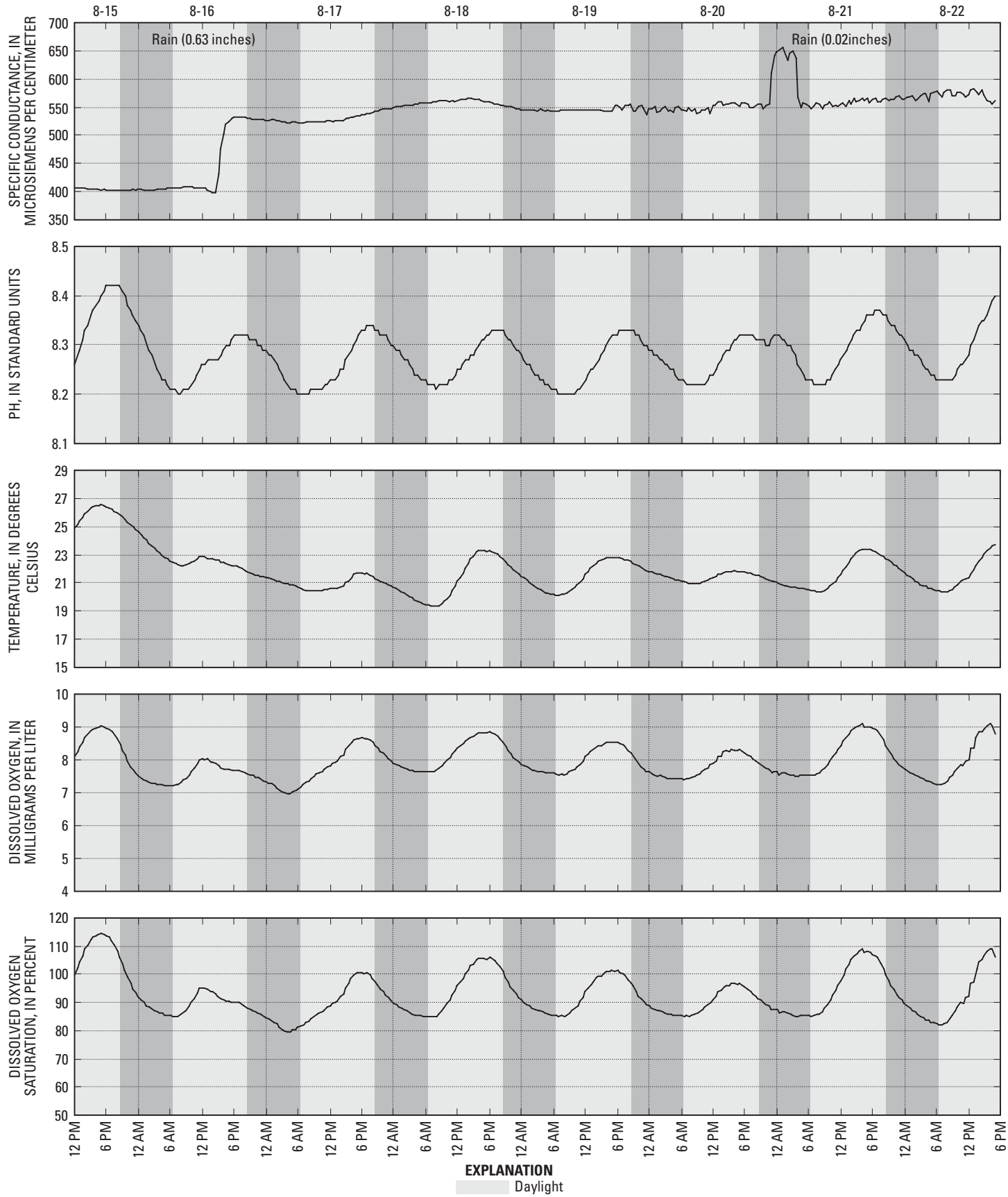

Figure 13. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Red River near Brushvale, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

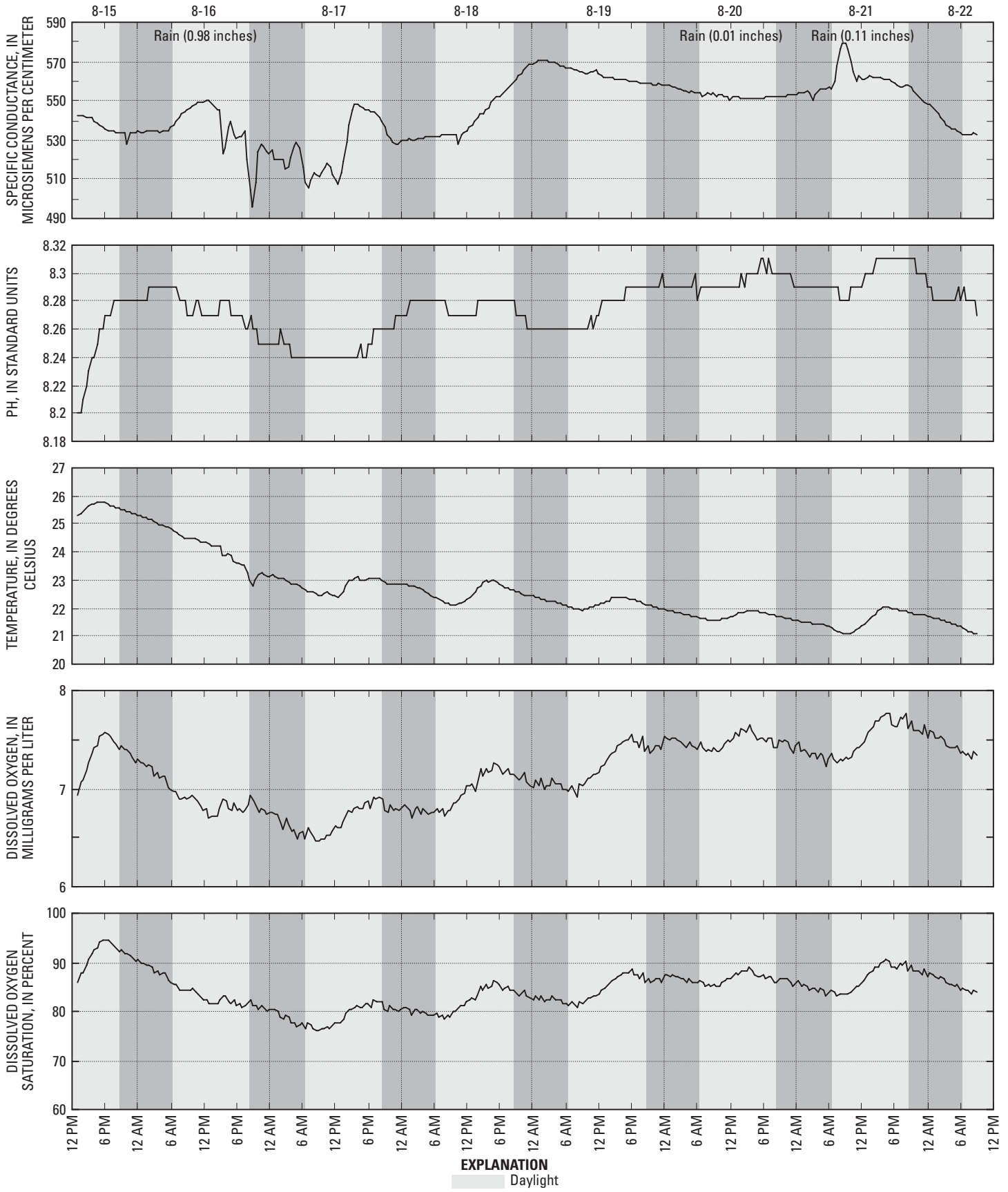

Figure 14. Specific conductance, pH, water temperature, dissolved oxygen, and percent oxygen saturation of the Red River near Moorhead, Minnesota. (Data were collected at 30 minute intervals using a submersible data recorder during August 15-22, 2000. Precipitation data source is the Minnesota Department of Natural Resources Climatology website (http://www.climate.umn.edu).)

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SUPPLEMENTAL INFORMATION

Table 1. Drainage area, latitude and longitude, land use, ecoregion for 12 sites located on six streams in Minnesota where diurnal water-quality measurements and benthic algae samples were collected during August 2000

[LAP = Lake Agassiz Plain; NLF= Northern Lakes and Forests, NCHF= North Central Hardwoods Forests, WCBP= Western Corn Belt Plains, NGP = Northern Glaciated Plains.]

Site number (shown on fig. 1)	Site Name	Site identifier	Drainage Area (mi^2)	U.S. Geological Survey Gaging Station Identifier[2]	Latitude	Longitude	Major Basin Land Use	Ecoregion
1	Crow Wing River near Nimrod, MN	CWR-72.3	1030	05244000	46°38'24"	94°52'46"	Forest	NLF
2	Crow Wing River near Staples, MN	CWR-35.5	2130	05244000	46°21'40"	94°43'22"	Forest	NLF/NCHF
3	Mississippi River near Aitkin, MN	UM-1055.9	6140	05227500	46°32'26"	93°42'26"	Forest	NLF
4	Mississippi River near Anoka, MN	UM-872	19,100	05288500	45°11'30"	93°23'42"	Mixed	NCHF
5	Rum River near Isanti, MN	RU-34	1232	05286000	45°29'36"	93°16'01"	Forest	NCHF
6	Rum River near St. Francis, MN	RU-18	1360	05286000	45°23'13"	93°21'27"	Forest	NCHF
7	Crow River near Rockford, MN	CR-23	2640	05280000	45°05'06"	93°44'08"	Agriculture	NCHF
8	Crow River near Dayton, MN	CR-0.2	2761	05280000	45°14'41"	93°31'24"	Agriculture	NCHF
9	Blue Earth River West of Winnebago, MN	BE-73.2	1000	05320000	43°46'10"	94°11'42"	Agriculture	WCP
10	Blue Earth River near Amboy, MN	BE-54	1055	05320000	43°53'41"	94°11'57"	Agriculture	WCP
11	Red River near Brushvale, MN	RED-536	4050	05054000	46°22'06"	96°39'21"	Agriculture	LAP/NGP
12	Red River near Moorhead, MN	RED-452	6800	05054000	46°52'26"	96°46'35"	Agriculture	LAP/NGP

[1] The code for the site number is comprised of two or three letters corresponding to the river followed by numbers that correpond to the river mile near the site location. For example the Crow Wing River near Nimrod, Minnesota (CWR-72.3) is located 72.3 miles upstream of the confluence of the Crow Wing and the Mississippi Rivers.

2 Refers to the nearest U.S. Geological Survey stream gaging station. USGS stream gages were not colocated with all sites.

Table 2. Site conditions at time of benthic algae collection and dates for diurnal water-quality measurements for 12 sites located on six Minnesota streams sampled during August 2000.

Site identifier	Start date for diurnal monitoring	End date for diurnal monitoring	Collection date for benthic algae (time)	Average Velocity (cubic feet per second)	Sechi disc depth (inches)	Water color-clarity
CWR-72.3	8/15/00	8/22/00	8/15/00	1.3	> 36	Clear-stained
CWR-35.5	8/16/00	8/22/00	8/16/00	1.5	> 36	Clear-stained
UM-1055.9	8/10/00	8/15/00	8/16/00	0.8	24	Brown-turbid
UM-872	8/10/00	8/15/00	8/9/00	0.6	24	Clear stained
RU-34	8/8/00	8/14/00	8/9/00	1.3	> 36	Clear-stained
RU-18	8/9/00	8/14/00	8/9/00	0.9	> 36	Clear-stained
CR-23	8/8/00	8/14/00	8/8/00	0.76	8	Brown-turbid
CR-0.2	8/8/00	8/14/00	8/8/00	0.6	10	Brown-turbid
BE-73.2	8/3/00	8/7/00	8/7/00	1.4	12	Green-turbid
BE-54	8/3/00	8/7/00	8/7/00	2.0	12	Green-turbid
RED-536	8/15/00	8/22/00	8/15/00	1.5	12	Brown-turbid
RED-452	8/15/00	8/22/00	8/15/00	0.9	6	Brown-turbid

Table 3. Median specific conductance, pH, water temperature, dissolved oxygen, and percent dissolved oxygen saturation for 12 sites located on six streams in Minnesota during August 2000.

[uS/cm, microsiemens per centimenter at 25 degrees Celsius, s.u., standard units, ^{o}C, degrees Celsius, mg/L, milligrams per liter; na, not available]

Site identifier	Specific Conductance, median (uS/cm)	pH, median (s.u.)	Water Temperature, median (^{o}C)	Dissolved oxygen, median (mg/L)	Dissolved oxygen saturation, median (percent)
CWR-72.3	298	8.38	19.92	7.31	82.5
CWR-35.5	389	na	19.52	7.43	83.2
UM-1055.9	290	8.21	24.43	6.79	83
UM-872	389	8.53	26.9	6.99	89.6
RU-34	323	8.37	24.53	8.78	108.4
RU-18	332	8.97	24.84	8.45	103.3
CR-23	651	8.53	26.15	8.49	109
CR-0.2	575	8.59	25.79	8.59	108.5
BE-73.2	590	8.16	23.36	8.24	98.4
BE-54	588	8.23	23.73	8.91	107.7
RED-536	547	8.28	21.60	7.8	90.3
RED-452	548	8.28	22.33	7.22	84.5

Table 4. Estimates of net community primary production and respiration for 12 sites located on six Minnesota streams sampled during August 2000.

[$g0_2/m^3$/hr, grams of oxygen per cubic meter per hour]

Site identifier	Estimates of net community primary production, maximum (gO_2/m^3/hr)							Estimates of net community respiration, maximum (gO_2/m^3/hr)						
	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
CWR-72.3	0.24	0.49	0.58	0.50	0.43	0.63	--	0.09	0.06	0.09	0.10	0.12	0.09	0.08
CWR-35.5	0.36	0.37	0.29	0.42	0.28	0.53	--	0.04	0.07	0.11	0.11	0.04	0.13	--
UM-1055.9	0.10	0.04	0.09	0.03	--	--	--	0.01	0.03	0.00	0.04	0.00	--	--
UM-872	0.43	0.15	0.36	0.33	--	--	--	0.27	0.28	0.22	0.28	0.24	--	--
RU-34	0.61	0.63	0.66	0.41	0.65	--	--	0.26	0.30	0.36	0.35	0.31	0.35	--
RU-18	0.72	0.65	0.31	0.69	--	--	--	0.28	0.23	0.22	0.18	0.25	--	--
CR-23	0.90	0.91	0.88	0.28	0.62	--	--	0.34	0.53	0.47	0.42	0.23	0.27	--
CR-0.2	0.96	0.82	0.76	0.47	0.94	--	--	0.39	0.48	0.44	0.40	0.35	0.51	--
BE-73.2	1.06	0.26	0.51	--	--	-	--	0.27	1.09	0.17	0.20	--	--	--
BE-54	1.10	1.07	0.61	--	--		--	0.28	0.40	0.27	0.25	--	--	--
RED-536	0.29	0.03	0.13	0.15	0.15	0.14	0.22	0.04	0.05	0.04	0.04	0.03	0.02	0.08
RED-452	0.04	0.06	0.05	0.06	0.05	0.08	--	0.05	0.04	0.01	0.00	0.02	0.03	0.03

Stream productivity and stream respiration estimates were quantified according to Sorrenson and others (1999). Briefly, Productivity estimates were determined by calculating the slope of the dissolved oxygen concentrations between 10 am and 3 pm The estimates define the net rate of oxygen accrual in grams of oxygen per hour (mg O_2/L/hr), which is equivalent to grams of oxygen per cubic meter per hour (g O_2/m^3/hr). Stream respiration was calculated in the same manner for oxygen concentrations between 12 am and 6 am.

Table 5. Chlorophyll-*a* content of benthic algae collected from rock and wood substrate from 12 sites located on six streams in Minnesota during August 2000.

[mg/m^2, miligram per square meter]

Site identifier	Chorophyll-*a* content (mg/m^2)	
	Wood substrate	Rock substrate
CWR-72.3	16.4	17.4
CWR-35.5	26.6	23.6
UM-1055.9	16.8	2.1
UM-872	117	150
RU-18	15.6	47.7
RU-34	40.5	68.5
CR-23	7.94	19
CR-0.2	8.22	19.5
BE-54	13.4	34.2
BE-73.2	3.98	17
RE-536	48.9	14.3
RE-452	7.53	57.9

Table 6. Total biovolume and density of benthic algae collected from rock and wood substrate from 12 sites located on six streams in Minnesota during August 2000

[$\mu m^3/cm$, cubic micrometer per square centimeter; cm^2 , square centimeter; --, not collected]

Site identifier	Total biovolume ($\mu m^3/cm^2$)		Total density (number of cells/cm^2)	
	Rock substrate	Wood substrate	Rock substrate	Wood substrate
CWR-72.3	113,923,900	58,355,787,392	1,291,601	581,917
CWR-35.5	541,846,200	529,357,200	1,082,148	1,799,878
UM-1055.9	90,862,517	146,236,416	246,234	203,397
UM-872	129,906,614	541,859,656	736,078	2,472,874
UM-872 (Replicate)	227,948,884	--	1,567,368	--
UM-872 (Replicate)	216,515,943	--	1,188,846	--
RU-34	484,437,457	2,871,319,970	1,618,846	656,460
RU-18	971,845,124	167,582,762	1,507,407	632,221
CR-23	224,446,205	22,257,629	1,260,949	112,129
CR-0.2	163,319,073	90,778,998	765,937	401,998
BE-73.2	205,407,100	36,778,565	1,790,662	188,540
BE-54	896,036,700	86,408,799	2,639,934	945,037
RED-536	99,078,874	618,333,300	622,254	1,554,338
RED-452	755,708,700	43,400,898	1,873,043	505,499

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000

[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Chlorophyta (Green Algae)														
Ankistrodesmus convolutus Corda											0.07			
Ankistrodesmus falcatus (Corda) Ralfs				0.04	0.10	0.06	0.04	0.09						
Chlamydomonas platystigma (Korshikoff) Pascher														
Chlorococcum sp. Meneghini	39.02	1.62	3.45		11.77	1.94	3.65	3.20	9.00	3.02	4.23		9.14	0.62
Cladophora sp. Kützing								53.21						
Closterium moniliferum (Bory) Ehrenberg									0.89					
Coelastrum astroideum De Not.					0.49		0.13							
Coelastrum microporum Nägeli												0.20		
Crucigenia crucifera (Wolle) Collins										0.12				
Crucigenia quadrata Morren						0.15								
Dictyosphaerium pulchellum Wood				0.12				0.01		0.17				
Didymogenes anomala (G.M. Smith) Hinkak										0.06				
Monoraphidium capricornutum (Printz) Nygaard						0.02						0.02		
Mougeotia sp. Agardh					1.38									
Nephroselmis sp. Stein								0.13						
Non-motile Chlorococcales (spherical, >10µm)					6.30									
Oedogonium sp. Link			0.77						10.64					2.60
Oocystis parva West & West						0.24	0.12	0.01	0.07	0.23				

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Pediastrum duplex Meyen								5.28	0.28					
Pediastrum tetras (Ehrenberg) Ralfs									0.43					
Phacotus sp. Perty														
Protoderma viride Kützing					1.94									
Pyramichlamys sp. Ettl						1.40								
Scenedesmus abundans (Kirchner) Chodat		0.03				0.06	0.03	0.08	0.48	0.71				
Scenedesmus acuminatus (Lagerheim) Chodat														
Scenedesmus bijuga (Turpin) Lagerheim				0.07			0.09	0.12					0.72	
Scenedesmus dimorphus (Turpin) Kützing								0.03		0.23				
Scenedesmus opoliensis v. carinatus Lemmermann				0.73	0.31		0.41	0.47				0.22		
Scenedesmus quadricauda (Turpin) de Brébisson							0.89	0.04	0.10	0.09		0.31		
Scenedesmus serratus (Corda) Bohlin							0.10	0.11						
Selenastrum gracile Reinsch														
Sphaerocystis schroeteri Chodat				0.63							0.23			
Spirogyra sp. Link														
Stigeoclonium sp. Kützing						0.81	12.05							
Tetraedron caudatum (Conda) Hansgirg								0.06						
Tetraedron minimum (Braun) Hansgirg									0.04					
Tetraedron regulare var. incus Teiling														

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Tetrastrum staurogeniaeforme (Schroeder) Lemmermann						0.07			0.15					
Chrysophyta														
Cyst (Chrysophyte)						0.15	0.44	0.05						
Cryptophyta (Cryptomonads)														
Cryptomonas erosa Ehrenberg									0.22					
Cryptomonas ovata Ehrenberg														0.20
Cyanophyta (Blue-Greens)														
Anabaena circinalis Rabenhorst														
Aphanocapsa delicatissima West & West														
Aphanocapsa elachista West & West	0.60		0.13											
Aphanocapsa koordersi Strom														
Aphanothece saxicola Nägeli														
Calothrix sp. Agardh		0.29	0.16		0.06			0.06						0.39
Chroococcus minimus (Keissler) Lemmermann					0.15	0.05			0.07	0.03				
Chroococcus minutus (Kützing) Nägeli				0.32		0.34								
Lyngbya digueti Gomont		0.15		0.54	1.96	0.40	0.37	0.44	0.25	0.19				
Lyngbya sp. 1 (small) Agardh		27.09												
Lyngbya sp. 3 Agardh					2.88			0.37						
Lyngbya sp. 4 Agardh							0.58							
Lyngbya subtilis West		1.64	0.45	2.65	1.97	1.18	0.16	0.15		0.14		0.25	0.97	

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Merismopedia tenuissima Lemmermann						0.01								
Non-motile blue-greens (>1 µm)	12.34	1.77	2.11	6.54	6.37	6.00	2.07	1.11	4.49	4.35	9.91	3.63	7.48	1.82
Nostoc sp. Vaucher														
Oscillatoria amphibia Agardh							0.08							
Oscillatoria chlorina Kützing ex Gomont		5.99	0.06	3.03		0.36		0.13				10.18		
Oscillatoria hamelii Frémy													3.90	16.24
Oscillatoria limnetica Lemmermann							0.06							
Oscillatoria sp. 4 Vaucher					1.84									
Oscillatoria tenuis Agardh				2.20	1.63	0.73	1.38			0.39		4.26		
Phormidium fragile (Meneghini) Gomont														
Phormidium jadinianum Gomont														
Pseudanabaena galeata Bocher			0.03	0.02										
Synechococcus elongatus Nägeli			0.10		0.43			0.06	0.49	0.22	0.16		0.10	0.06
Xenococcus sp. Thuret								0.13						
Bacillariophyceae (Diatoms)														
Achnanthes exigua Grunow														
Achnanthes lanceolata ssp. dubia (Grunow) Lange-Bertalot							0.52							
Achnanthes lanceolata ssp. frequentissima Lange-Bertalot				0.32			0.33							
Achnanthes lanceolata v. frequentissima Lange-Bertalot							0.33							
Achnanthes minutissima Kützing	0.18	0.05		0.19	0.14	0.24	0.00	0.02			0.16	0.09	0.04	

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Amphora montana Krasske				3.88				0.98						
Amphora pediculus (Kützing) Grunow	1.08	0.69	0.06	14.91	12.16	28.52	6.95	0.85	0.13	0.08	1.86	0.18	0.91	
Amphora veneta Kützing														
Cocconeis pediculus Ehrenberg	12.14			21.22		2.57								15.16
Cocconeis placentula v. lineata (Ehrenberg) Van Heurck	24.33	14.09	1.83	1.70	1.77	2.31	0.74	8.10	11.03				9.70	3.64
Cocconeis placentula v. pseudolineata Geitler								0.30						
Cyclostephanos invisitatus (Hohn & Hel.) Ther., Stoerm. & Håkansson														
Cyclotella bodanica Grunow												3.92		
Cyclotella meneghiniana Kützing				1.02	0.77	4.44	21.82	0.88	14.98	55.45	2.57	55.14		1.29
Cyclotella sp. 1 (Kützing) de Brébisson						0.08			0.47	0.09		0.16		0.63
Cymbella affinis Kützing				7.92				1.50						
Cymbella minuta Hilse	1.27				1.93	2.11							3.81	
Cymbella silesiaca Bleisch					1.52									
Cymbella sinuata Gregory						2.56	0.96							
Cymbellonitzschia sp. Hustedt	0.55													
Diatoma vulgaris Bory													3.05	
Diploneis finnica (Ehrenberg) Cleve									0.13					
Epithemia sorex Kützing								0.11						
Epithemia sorex v. sorex Kützing							1.81							
Epithemia turgida v. westermannii (Ehrenberg) Grunow			41.02											

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Fragilaria capucina Desmaziéres									0.48					
Fragilaria capucina v. vaucheriae (Kützing) Lange-Bertalot														
Fragilaria construens (Ehrenberg) Grunow								0.43						
Fragilaria construens f. venter (Ehrenberg) Hustedt	3.68	0.77		0.59	0.46	0.38		0.31					0.41	
Fragilaria leptostauron v. dubia (Grunow) Hustedt	1.77	0.64					3.86							
Fragilaria pinnata v. pinnata Ehrenberg														
Gomphonema augur Ehrenberg									5.38					
Gomphonema gracile Ehrenberg														
Gomphonema olivaceum (Hornemann) de Brébisson				3.33	9.27	5.84	2.32	1.04						
Gomphonema parvulum (Kützing) Kützing		0.45	2.82	0.36	1.86	6.91	0.14	0.08	0.44		1.09		0.61	
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot								0.15	0.22		1.05			
Gyrosigma scalproides (Radenhorst) Cleve														
Gyrosigma sp. Hassall														
Gyrosigma spencerii (W. Smith) Cleve			4.05										13.34	20.79
Melosira cf. distans Agardh								1.10						
Melosira granulata (Ehrenberg) Ralfs									20.19	2.76		1.60		
Melosira varians Agardh		43.74					0.23			8.47				
Navicula absoluta Hustedt							0.31							

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)

[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Navicula capitata Ehrenberg					0.55									
Navicula cf gregaria Donkin						0.48		0.77						
Navicula cf. lacunolaciniata Lange-Bertalot & Bonik						0.10	0.33				0.23			0.11
Navicula cryptocephala Kützing			0.91	0.80	2.57	1.04	1.74			0.86		1.50	3.43	1.52
Navicula cryptotenella Lange-Bertalot		0.10		0.21										
Navicula cuspidata (Kützing) Kützing								2.90						
Navicula decussis v. decussis Østrup							2.94	5.02						
Navicula erifuga Lange-Bertalot							2.49							
Navicula goeppertiana v. goeppertiana (Bleisch) H.L. Smith														
Navicula menisculus v. grunowii Lange-Bertalot	0.48	0.63		4.53	2.92	0.60	1.04	0.85	0.12				0.82	
Navicula pupula Kützing						2.61	0.77							
Navicula rhynchocephala Kützing														
Navicula salinarum Grunow				8.34		2.56	4.63	2.32						
Navicula sp. Bory					0.15									
Navicula subminuscula Manguin						0.09	0.30							
Navicula viridula v. germainii (Wallace) Lange-Bertalot	2.57		2.92	8.11	19.64	5.74	7.42	2.90	2.66	9.58				
Nitzschia acicularis (Kützing) W. Smith									0.77	7.67		2.12		0.76
Nitzschia constricta (Kützing) Ralfs														

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Nitzschia dissipata (Kützing) Grunow							4.39							
Nitzschia fonticola Grunow			0.16	3.46	1.99	1.45	3.55	0.60		0.13	4.65	4.08	3.66	
Nitzschia fonticola v. pelagica Hustedt		0.04												
Nitzschia gracilis Hantzsch							0.66	0.09	2.41	1.88	32.24	0.59	2.29	12.16
Nitzschia inconspicua Grunow				0.05	0.02	0.04					0.10		0.03	
Nitzschia intermedia Hantzsch										2.30				
Nitzschia palea (Kützing) W. Smith						0.44	2.21		0.25	0.38	13.96	1.33	1.37	0.95
Nitzschia perminuta (Grunow) Peragallo		0.10												
Nitzschia pumila Hustedt						0.68								
Nitzschia reversa W. Smith											3.49	6.41		3.05
Nitzschia sigmoidea (Nitzsch) W. Smith									6.14					
Nitzschia sp. Hassall														
Pinnularia microstauron (Ehrenberg) Cleve						11.74								
Rhoicosphenia curvata (Kützing) Grunow		0.13	38.96	2.16	2.72	2.48	4.17	3.17	3.95				3.02	14.19
Stephanodiscus hantzschii (8-11µm) Grunow										0.41				
Stephanodiscus medius Håkansson												3.81		
Stephanodiscus niagarae Ehrenberg														
Surirella sp. Turpin														3.81
Surirella visurgis Hustedt											9.31			

Table 7. Relative biovolume (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872_1	UM-872_1	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Synedra tenera W. Smith							0.14							
Synedra ulna v. ulna (Nitzsch) Lange-Bertalot							0.24	0.15	2.63					
Pyrrhophyta (Dinoflagellates)														
Gymnodinium sp. 3 Stein								0.04						
Euglenophyta														
Euglena sp. Ehrenberg											14.69			
Trachelomonas volvocina Ehrenberg														
Miscellaneous														
Batrachospermum vagum (Roth) Agardh													31.19	

[1]Quality assurance sample

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000.
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Chlorophyta (Green Algae)												
Ankistrodesmus convolutus Corda				0.02		0.01		0.04				
Ankistrodesmus falcatus (Corda) Ralfs							0.43	0.98				0.60
Chlamydomonas platystigma (Korshikoff) Pascher					0.01							
Chlorococcum sp. Meneghini	0.02	1.36		4.16	0.01	3.39		2.21	6.13		2.72	4.41
Cladophora sp. Kützing	99.73				6.36							
Closterium moniliferum (Bory) Ehrenberg									0.13			
Coelastrum astroideum De Not.								0.13				
Coelastrum microporum Nägeli												
Crucigenia crucifera (Wolle) Collins						0.15						
Crucigenia quadrata Morren												
Dictyosphaerium pulchellum Wood												
Didymogenes anomala (G.M. Smith) Hinkak												
Monoraphidium capricornutum (Printz) Nygaard												
Mougeotia sp. Agardh												
Nephroselmis sp. Stein												
Non-motile Chlorococcales (spherical, >10µm)												
Oedogonium sp. Link			44.13									
Oocystis parva West & West							0.24	0.79				
Pediastrum duplex Meyen												
Pediastrum tetras (Ehrenberg) Ralfs		0.71										
Phacotus sp. Perty									0.39			
Protoderma viride Kützing												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Pyramichlamys sp. Ettl												
Scenedesmus abundans (Kirchner) Chodat					0.02			0.09		0.35		
Scenedesmus acuminatus (Lagerheim) Chodat								0.34				
Scenedesmus bijuga (Turpin) Lagerheim												
Scenedesmus dimorphus (Turpin) Kützing	0.00											
Scenedesmus opoliensis v. carinatus Lemmermann				0.21	0.02			2.72		0.94		
Scenedesmus quadricauda (Turpin) de Brébisson						0.10		0.26	0.16	1.12	0.30	
Scenedesmus serratus (Corda) Bohlin	0.00	0.08				0.26						
Selenastrum gracile Reinsch								0.76				
Sphaerocystis schroeteri Chodat	0.00	0.29										
Spirogyra sp. Link					86.86							
Stigeoclonium sp. Kützing												
Tetraedron caudatum (Conda) Hansgirg												
Tetraedron minimum (Braun) Hansgirg												
Tetraedron regulare var. incus Teiling								0.08				
Tetrastrum staurogeniaeforme (Schroeder) Lemmermann							0.16	0.13				
Chrysophyta												
Cyst (Chrysophyte)	0.01						0.32				0.27	
Cryptophyta (Cryptomonads)												
Cryptomonas erosa Ehrenberg												
Cryptomonas ovata Ehrenberg					0.02							
Cyanophyta (Blue-Greens)												
Anabaena circinalis Rabenhorst					0.03							

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Aphanocapsa delicatissima West & West				0.00								
Aphanocapsa elachista West & West			0.01									
Aphanocapsa koordersi Strom							0.90				0.76	
Aphanothece saxicola Nägeli											1.06	
Calothrix sp. Agardh						0.38						
Chroococcus minimus (Keissler) Lemmermann				0.07		0.04						
Chroococcus minutus (Kützing) Nägeli			0.06			0.05			0.14			
Lyngbya digueti Gomont		5.43		0.35		0.16	0.36					
Lyngbya sp. 1 (small) Agardh		0.95										
Lyngbya sp. 3 Agardh												
Lyngbya sp. 4 Agardh												
Lyngbya subtilis West			0.30	0.22	0.00	0.34	1.76	2.51	0.10		1.53	
Merismopedia tenuissima Lemmermann												
Non-motile blue-greens (>1 µm)	0.01	2.30	1.40	3.37	0.27	3.64	6.26	4.59	6.53	17.51	2.55	11.15
Nostoc sp. Vaucher									0.33			
Oscillatoria amphibia Agardh									0.42			
Oscillatoria chlorina Kützing ex Gomont	0.02	2.22	0.08			0.63						
Oscillatoria hamelii Frémy											61.07	
Oscillatoria limnetica Lemmermann												
Oscillatoria sp. 4 Vaucher												
Oscillatoria tenuis Agardh				1.69	0.03	0.78			2.15			
Phormidium fragile (Meneghini) Gomont												0.17
Phormidium jadinianum Gomont	0.00											
Pseudanabaena galeata Bocher	0.00	0.03										

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Synechococcus elongatus Nägeli		0.06	0.09	0.59	0.00	0.01	0.33	0.17	0.02	0.07		1.27
Xenococcus sp. Thuret									0.12			
Bacillariophyceae (Diatoms)												
Achnanthes exigua Grunow		0.43										
Achnanthes lanceolata ssp. dubia (Grunow) Lange-Bertalot				0.36							0.20	
Achnanthes lanceolata ssp. frequentissima Lange-Bertalot						0.09						
Achnanthes lanceolata v. frequentissima Lange-Bertalot												
Achnanthes minutissima Kützing	0.00			0.05	0.00	0.15	0.05					
Amphora montana Krasske				24.05	0.42	6.21	1.32				1.27	
Amphora pediculus (Kützing) Grunow	0.00	0.67		6.52	0.28	4.13		0.67			0.48	0.60
Amphora veneta Kützing	0.00							3.37				
Cocconeis pediculus Ehrenberg	0.01			10.94				5.46				7.97
Cocconeis placentula v. lineata (Ehrenberg) Van Heurck	0.07	38.18	10.87	5.99	0.60	4.27	8.99	1.43			0.27	
Cocconeis placentula v. pseudolineata Geitler												
Cyclostephanos invisitatus (Hohn & Hel.) Ther., Stoerm. & Håkansson										2.79		
Cyclotella bodanica Grunow												
Cyclotella meneghiniana Kützing				2.57	0.18	0.55	3.12	17.15	3.92	31.58	1.33	
Cyclotella sp. 1 (Kützing) de Brébisson					0.00	0.14					0.04	
Cymbella affinis Kützing												
Cymbella minuta Hilse	0.00			4.95								
Cymbella silesiaca Bleisch	0.01											
Cymbella sinuata Gregory	0.00				0.02	0.08						
Cymbellonitzschia sp. Hustedt												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Diatoma vulgaris Bory												
Diploneis finnica (Ehrenberg) Cleve					0.00							
Epithemia sorex Kützing												
Epithemia sorex v. sorex Kützing						15.90						
Epithemia turgida v. westermannii (Ehrenberg) Grunow							13.32					
Fragilaria capucina Desmaziéres	0.00											
Fragilaria capucina v. vaucheriae (Kützing) Lange-Bertalot			0.25	0.29								
Fragilaria construens (Ehrenberg) Grunow					0.09	0.58						
Fragilaria construens f. venter (Ehrenberg) Hustedt			0.15		0.01	3.71						
Fragilaria leptostauron v. dubia (Grunow) Hustedt	0.01		0.66		0.14							
Fragilaria pinnata v. pinnata Ehrenberg	0.00											
Gomphonema augur Ehrenberg								4.09				
Gomphonema gracile Ehrenberg											1.09	
Gomphonema olivaceum (Hornemann) de Brébisson				4.22		1.55					3.75	
Gomphonema parvulum (Kützing) Kützing	0.01	1.52	0.67	0.08	0.08	2.51	1.22		1.70		1.12	0.99
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot					0.02	0.80		0.19				
Gyrosigma scalproides (Radenhorst) Cleve			7.97									
Gyrosigma sp. Hassall	0.01											
Gyrosigma spencerii (W. Smith) Cleve											3.82	
Melosira cf. distans Agardh												
Melosira granulata (Ehrenberg) Ralfs							11.51	21.27	3.50	8.26		13.53
Melosira varians Agardh			18.10	5.00	0.07							
Navicula absoluta Hustedt												

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Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Navicula capitata Ehrenberg												
Navicula cf gregaria Donkin								0.84				4.47
Navicula cf. lacunolaciniata Lange-Bertalot & Bonik				0.02	0.01	0.62	0.07	0.06	0.12		0.07	0.40
Navicula cryptocephala Kützing	0.00	2.08	0.24	1.32	0.05	0.78			5.32		4.05	26.80
Navicula cryptotenella Lange-Bertalot				0.77		0.47						
Navicula cuspidata (Kützing) Kützing						8.28					4.00	
Navicula decussis v. decussis Østrup					0.62	0.46						
Navicula erifuga Lange-Bertalot							1.90	0.56				
Navicula goeppertiana v. goeppertiana (Bleisch) H.L. Smith	0.00											
Navicula menisculus v. grunowii Lange-Bertalot	0.00	13.14			0.09	2.24		0.88	0.12		0.20	2.78
Navicula pupula Kützing						2.68	1.88					
Navicula rhynchocephala Kützing						1.81						
Navicula salinarum Grunow	0.03		0.38	2.81	0.11	3.98	0.71	3.51				
Navicula sp. Bory	0.00			0.26					0.04			
Navicula subminuscula Manguin								0.15			0.24	
Navicula viridula v. germainii (Wallace) Lange-Bertalot	0.01	4.12	1.43	3.30	0.84	7.25	32.38	15.05	16.56	15.57		4.01
Nitzschia acicularis (Kützing) W. Smith	0.00							1.50	4.34			
Nitzschia constricta (Kützing) Ralfs				4.12					2.96			
Nitzschia dissipata (Kützing) Grunow				0.29								
Nitzschia fonticola Grunow				0.37	0.10	2.52	6.71	0.37	9.94	2.43	0.94	
Nitzschia fonticola v. pelagica Hustedt												
Nitzschia gracilis Hantzsch					0.06	0.23		1.06	8.20			5.95
Nitzschia inconspicua Grunow												

Table 8. Relative biovolume (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000. (Continued)
[site identifiers are defined in Table 1];CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon												
Nitzschia intermedia Hantzsch					0.20	1.00		5.99		15.76		
Nitzschia palea (Kützing) W. Smith				0.13	0.01	0.44	0.06		2.26	2.34	2.92	4.32
Nitzschia perminuta (Grunow) Peragallo												
Nitzschia pumila Hustedt						0.27						
Nitzschia reversa W. Smith												
Nitzschia sigmoidea (Nitzsch) W. Smith											3.15	4.51
Nitzschia sp. Hassall	0.02	17.37	3.98									
Pinnularia microstauron (Ehrenberg) Cleve												
Rhoicosphenia curvata (Kützing) Grunow	0.02	9.04	9.20	6.34	1.38	15.98	5.99	0.60				6.09
Stephanodiscus hantzschii (8-11µm) Grunow										1.28		
Stephanodiscus medius Håkansson												
Stephanodiscus niagarae Ehrenberg									24.38			
Surirella sp. Turpin												
Surirella visurgis Hustedt												
Synedra tenera W. Smith				0.16		0.28					0.81	
Synedra ulna v. ulna (Nitzsch) Lange-Bertalot				4.41								
Pyrrhophyta (Dinoflagellates)												
Gymnodinium sp. 3 Stein						0.10						
Euglenophyta												
Euglena sp. Ehrenberg												
Trachelomonas volvocina Ehrenberg					0.04							
Miscellaneous												
Batrachospermum vagum (Roth) Agardh					0.96							

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000

[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Taxon														
Chlorophyta (Green Algae)														
Ankistrodesmus convolutus Corda											0.8			
Ankistrodesmus falcatus (Corda) Ralfs				0.3	0.4	0.2	0.3	0.7						
Chlamydomonas platystigma (Korshikoff) Pascher														
Chlorococcum sp. Meneghini	35.3	18.3	14.6		14.4	7.9	12.6	23.7	18.4	7.4	3.2		9.7	5.6
Cladophora sp. Kützing								0.2						
Closterium moniliferum (Bory) Ehrenberg									0.4					
Coelastrum astroideum De Not.					0.2		0.3							
Coelastrum microporum Nägeli												0.5		
Crucigenia crucifera (Wolle) Collins										0.2				
Crucigenia quadrata Morren						0.2								
Dictyosphaerium pulchellum Wood				0.3				0.2		0.2				
Didymogenes anomala (G.M. Smith) Hinkak										0.2				
Monoraphidium capricornutum (Printz) Nygaard						0.4						0.5		
Mougeotia sp. Agardh					0.2									
Nephroselmis sp. Stein								0.2						
Non-motile Chlorococcales (spherical, >10µm)					0.6									
Oedogonium sp. Link			0.3						0.4					1.4
Oocystis parva West & West						0.4	0.3	0.2	0.4	0.2				
Pediastrum duplex Meyen								0.2	0.4					
Pediastrum tetras (Ehrenberg) Ralfs									0.4					
Phacotus sp. Perty														
Protoderma viride Kützing					0.4									
Pyramichlamys sp. Ettl						0.2								

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Scenedesmus abundans (Kirchner) Chodat		0.3				0.2	0.3	0.5	1.1	1.5				
Scenedesmus acuminatus (Lagerheim) Chodat														
Scenedesmus bijuga (Turpin) Lagerheim				0.3			0.3	0.5					0.9	
Scenedesmus dimorphus (Turpin) Kützing								0.2		0.2				
Scenedesmus opoliensis v. carinatus Lemmermann				0.3	0.1		0.5	0.7				0.5		
Scenedesmus quadricauda (Turpin) de Brébisson							0.8	0.5	0.4	0.2		0.9		
Scenedesmus serratus (Corda) Bohlin							0.3	0.5						
Selenastrum gracile Reinsch														
Sphaerocystis schroeteri Chodat				0.6							0.8			
Spirogyra sp. Link														
Stigeoclonium sp. Kützing						0.2	0.5							
Tetraedron caudatum (Conda) Hansgirg								0.2						
Tetraedron minimum (Braun) Hansgirg									0.4					
Tetraedron regulare var. incus Teiling														
Tetrastrum staurogeniaeforme (Schroeder) Lemmermann						0.2			0.4					
Chrysophyta														
Cyst (Chrysophyte)						0.2	0.5	0.2						
Cryptophyta (Cryptomonads)														
Cryptomonas erosa Ehrenberg									0.4					
Cryptomonas ovata Ehrenberg														1.4
Cyanophyta (Blue-Greens)														
Anabaena circinalis Rabenhorst														
Aphanocapsa delicatissima West & West														

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Aphanocapsa elachista West & West	0.6		0.3											
Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Aphanocapsa koordersi Strom														
Aphanothece saxicola Nägeli														
Calothrix sp. Agardh		0.3	0.5		0.2			0.1						1.4
Chroococcus minimus (Keissler) Lemmermann					0.4	0.2			0.4	0.2				
Chroococcus minutus (Kützing) Nägeli				0.3		0.2								
Lyngbya digueti Gomont		1.2		0.6	1.0	0.4	0.5	1.1	0.4	0.2				
Lyngbya sp. 1 (small) Agardh		0.3												
Lyngbya sp. 3 Agardh					0.2			0.2						
Lyngbya sp. 4 Agardh							0.3							
Lyngbya subtilis West		6.7	3.5	4.3	2.4	3.5	0.8	1.4		0.2		0.5	2.2	
Merismopedia tenuissima Lemmermann						0.2								
Non-motile blue-greens (>1 µm)	57.9	47.2	41.5	61.4	49.3	58.1	33.0	38.0	42.5	49.4	60.5	65.5	63.4	39.0
Nostoc sp. Vaucher														
Oscillatoria amphibia Agardh							0.3							
Oscillatoria chlorina Kützing ex Gomont		6.4	0.3	0.3		0.4		0.2				0.3		
Oscillatoria hamelii Frémy													1.3	2.8
Oscillatoria limnetica Lemmermann							0.3							
Oscillatoria sp. 4 Vaucher					0.2									
Oscillatoria tenuis Agardh				2.3	0.6	0.5	0.1			0.2		0.5		
Phormidium fragile (Meneghini) Gomont														
Phormidium jadinianum Gomont														
Pseudanabaena galeata Bocher			0.3	0.3										
Synechococcus elongatus Nägeli			8.1		13.2			8.1	18.4	9.9	1.6		3.5	5.6
Xenococcus sp. Thuret								0.2						
Bacillariophyceae (Diatoms)														

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Achnanthes exigua Grunow														
Achnanthes lanceolata ssp. dubia (Grunow) Lange-Bertalot							0.5							
Achnanthes lanceolata ssp. frequentis-sima Lange-Bertalot				0.3			0.5							
Achnanthes lanceolata v. frequentissima Lange-Bertalot							0.5							
Achnanthes minutissima Kützing	0.6	0.9		2.0	1.2	1.6	0.0	0.5			0.8	1.4	0.4	
Amphora montana Krasske				0.2				0.2						
Amphora pediculus (Kützing) Grunow	0.6	2.6	0.3	14.8	7.2	14.3	7.9	2.7	0.4	0.2	3.2	0.9	2.2	
Amphora veneta Kützing														
Cocconeis pediculus Ehrenberg	0.6			0.9		0.1								1.4
Cocconeis placentula v. lineata (Ehrenberg) Van Heurck	2.5	8.7	1.1	0.3	0.4	0.5	0.3	3.2	2.1				2.6	1.4
Cocconeis placentula v. pseudolineata Geitler								0.2						
Cyclostephanos invisitatus (Hohn & Hel.) Ther., Stoerm. & Håkansson														
Cyclotella bodanica Grunow												0.5		
Cyclotella meneghiniana Kützing				0.3	0.6	0.9	7.9	0.7	5.0	23.7	0.8	11.4		2.8
Cyclotella sp. 1 (Kützing) de Brébisson						0.2			1.1	0.2		2.3		5.6
Cymbella affinis Kützing				0.2				0.1						
Cymbella minuta Hilse	0.3				0.1	0.2							0.4	
Cymbella silesiaca Bleisch					0.2									
Cymbella sinuata Gregory						0.4	0.5							
Cymbellonitzschia sp. Hustedt	0.3													
Diatoma vulgaris Bory													0.1	
Diploneis finnica (Ehrenberg) Cleve									0.4					
Epithemia sorex Kützing								0.1						
Epithemia sorex v. sorex Kützing							0.3							
Epithemia turgida v. westermannii (Ehrenberg) Grunow			0.3											

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Fragilaria capucina Desmazières									0.4					
Fragilaria capucina v. vaucheriae (Kützing) Lange-Bertalot														
Fragilaria construens (Ehrenberg) Grunow								0.5						
Fragilaria construens f. venter (Ehrenberg) Hustedt	0.8	1.2		0.9	0.2	0.2		1.8					0.4	
Fragilaria leptostauron v. dubia (Grunow) Hustedt	0.3	0.3					0.3							
Fragilaria pinnata v. pinnata Ehrenberg														
Gomphonema augur Ehrenberg									0.3					
Gomphonema gracile Ehrenberg														
Gomphonema olivaceum (Hornemann) de Brébisson				0.3	0.6	0.5	0.5	0.5						
Gomphonema parvulum (Kützing) Kützing		1.4	4.3	0.3	0.4	1.1	0.3	0.2	0.4		0.8		0.9	
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot								0.5	0.4		2.4			
Gyrosigma scalproides (Radenhorst) Cleve														
Gyrosigma sp. Hassall														
Gyrosigma spencerii (W. Smith) Cleve			0.3										0.4	0.7
Melosira cf. distans Agardh								0.2						
Melosira granulata (Ehrenberg) Ralfs									1.1	1.0		0.9		
Melosira varians Agardh		1.2					0.1			0.5				
Navicula absoluta Hustedt							0.5							
Navicula capitata Ehrenberg					0.2									
Navicula cf gregaria Donkin						0.2		0.5						
Navicula cf. lacunolaciniata Lange-Bertalot & Bonik						1.1	2.6				1.6			4.2
Navicula cryptocephala Kützing			0.5	0.3	0.6	0.5	1.0			0.2		0.9	0.9	2.8

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Navicula cryptotenella Lange-Bertalot		0.3		0.3										
Navicula cuspidata (Kützing) Kützing								0.2						
Navicula decussis v. decussis Østrup							0.5	1.4						
Navicula erifuga Lange-Bertalot							0.5							
Navicula goeppertiana v. goeppertiana (Bleisch) H.L. Smith														
Navicula menisculus v. grunowii Lange-Bertalot	0.1	2.0		2.3	0.6	0.4	1.6	1.6	0.4				2.6	
Navicula pupula Kützing						0.4	0.3							
Navicula rhynchocephala Kützing														
Navicula salinarum Grunow				0.9		0.4	1.0	0.7						
Navicula sp. Bory					0.2									
Navicula subminuscula Manguin						0.2	0.5							
Navicula viridula v. germainii (Wallace) Lange-Bertalot	0.1		0.3	0.9	1.0	0.5	0.8	0.7	0.3	0.5				
Nitzschia acicularis (Kützing) W. Smith									0.7	1.2		2.7		2.8
Nitzschia constricta (Kützing) Ralfs														
Nitzschia dissipata (Kützing) Grunow							3.4							
Nitzschia fonticola Grunow			0.3	2.6	1.4	1.1	6.0	2.0		0.2	1.6	3.2	1.8	
Nitzschia fonticola v. pelagica Hustedt		0.3												
Nitzschia gracilis Hantzsch							0.8	0.2	0.7	0.7	5.6	0.5	2.6	5.6
Nitzschia inconspicua Grunow				0.6	0.2	0.5					0.8		0.4	
Nitzschia intermedia Hantzsch										0.2				
Nitzschia palea (Kützing) W. Smith						0.5	6.5		0.4	0.2	12.9	3.6	1.8	7.0
Nitzschia perminuta (Grunow) Peragallo		0.3												
Nitzschia pumila Hustedt						0.4								
Nitzschia reversa W. Smith											0.8	2.3		1.4
Nitzschia sigmoidea (Nitzsch) W. Smith									0.4					

Table 9. Relative density (in percent) of benthic algae collected from rock substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	UM-872$_1$	UM-872$_1$	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Nitzschia sp. Hassall														
Pinnularia microstauron (Ehrenberg) Cleve						0.2								
Rhoicosphenia curvata (Kützing) Grunow		0.3	23.3	0.9	1.0	0.7	2.1	3.2	1.4				0.9	7.0
Stephanodiscus hantzschii (8-11µm) Grunow										0.2				
Stephanodiscus medius Håkansson												0.5		
Stephanodiscus niagarae Ehrenberg														
Surirella sp. Turpin														0.4
Surirella visurgis Hustedt											0.8			
Synedra tenera W. Smith							0.5							
Synedra ulna v. ulna (Nitzsch) Lange-Bertalot							0.1	0.1	0.4					
Pyrrhophyta (Dinoflagellates)														
Gymnodinium sp. 3 Stein								0.2						
Euglenophyta														
Euglena sp. Ehrenberg											0.8			
Trachelomonas volvocina Ehrenberg														
Miscellaneous														
Batrachospermum vagum (Roth) Agardh													0.4	

[1]Quality assurance sample

Table 10. Relative density (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000

[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Chlorophyta (Green Algae)												
Ankistrodesmus convolutus Corda				0.5		0.2		0.4				
Ankistrodesmus falcatus (Corda) Ralfs							0.4	1.5				0.8
Chlamydomonas platystigma (Korshikoff) Pascher					0.2							
Chlorococcum sp. Meneghini	15.7	9.0		10.5	1.1	7.6		5.7	7.9		7.2	8.5
*Cladophora sp.*Kützing	0.2				0.2							
Closterium moniliferum (Bory) Ehrenberg									0.2			
Coelastrum astroideum De Not.								0.4				
Coelastrum microporum Nägeli												
Crucigenia crucifera (Wolle) Collins						0.2						
Crucigenia quadrata Morren												
Dictyosphaerium pulchellum Wood												
Didymogenes anomala (G.M. Smith) Hinkak												
Monoraphidium capricornutum (Printz) Nygaard												
Mougeotia sp. Agardh												
Nephroselmis sp. Stein												
Non-motile Chlorococcales (spherical, >10µm)												
Oedogonium sp. Link			1.0									
Oocystis parva West & West							0.4	1.1				
Pediastrum duplex Meyen												
Pediastrum tetras (Ehrenberg) Ralfs		0.2										
Phacotus sp. Perty									0.2			
Protoderma viride Kützing												
Pyramichlamys sp. Ettl												
Scenedesmus abundans (Kirchner) Chodat					0.7			0.4		0.6		
Scenedesmus acuminatus (Lagerheim) Chodat								0.4				
Scenedesmus bijuga (Turpin) Lagerheim												

Table 10. Relative density (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Scenedesmus dimorphus (Turpin) Kützing	0.2											
Scenedesmus opoliensis v. carinatus Lemmermann				0.5	0.2			0.8		0.6		
Scenedesmus quadricauda (Turpin) de Brébisson						0.2		0.4	0.2	1.9	0.7	
Scenedesmus serratus (Corda) Bohlin	0.2	0.1				0.4						
Selenastrum gracile Reinsch								0.4				
Sphaerocystis schroeteri Chodat	0.6	0.4										
Spirogyra sp. Link					0.4							
Stigeoclonium sp. Kützing												
Tetraedron caudatum (Conda) Hansgirg												
Tetraedron minimum (Braun) Hansgirg												
Tetraedron regulare var. incus Teiling								0.4				
Tetrastrum staurogeniaeforme (Schroeder) Lemmermann							0.4	0.4				
Chrysophyta												
Cyst (Chrysophyte)	0.2						0.4				0.7	
Cryptophyta (Cryptomonads)												
Cryptomonas erosa Ehrenberg												
Cryptomonas ovata Ehrenberg					0.2							
Cyanophyta (Blue-Greens)												
Anabaena circinalis Rabenhorst					0.4							
Aphanocapsa delicatissima West & West				0.3								
Aphanocapsa elachista West & West			0.3									
Aphanocapsa koordersi Strom							0.4				0.7	
Aphanothece saxicola Nägeli											0.7	
Calothrix sp. Agardh						0.2						
Chroococcus minimus (Keissler) Lemmermann				0.3		0.2						
Chroococcus minutus (Kützing) Nägeli			0.3			0.2			0.2			

Table 10. Relative density (in percent) of benthic algae collected from wood substrate at 12 sites located on six streams in Minnesota during August 2000 (Continued)
[site identifiers are defined in Table 1; CWR, Crow Wing River; UM, Mississippi River; RU, Rum River; CR, Crow River; BE, Blue Earth River; RED, Red River of the North]

Site identifier	CWR-72.3	CWR-35.5	UM-1055.9	UM-872	RU-34	RU-18	CR-23	CR-0.2	BE-73.2	BE-54	RED-536	RED-452
Lyngbya digueti Gomont		8.4		0.3		0.2	0.4					
Lyngbya sp. 1 (small) Agardh		0.2										
Lyngbya sp. 3 Agardh												
Lyngbya sp. 4 Agardh												
Lyngbya subtilis West			2.8	1.3	0.2	2.0	3.0	8.0	0.2		2.2	
Merismopedia tenuissima Lemmermann												
Non-motile blue-greens (>1 µm)	59.3	36.0	53.6	39.3	61.7	51.3	66.1	55.2	67.8	85.2	54.0	51.0
Nostoc sp. Vaucher									0.2			
Oscillatoria amphibia Agardh									0.6			
Oscillatoria chlorina Kützing ex Gomont	2.0	2.4	0.7			0.6						
Oscillatoria hamelii Frémy											8.6	
Oscillatoria limnetica Lemmermann												
Oscillatoria sp. 4 Vaucher												
Oscillatoria tenuis Agardh				1.3	0.2	0.4			0.2			
Phormidium fragile (Meneghini) Gomont												0.8
Phormidium jadinianum Gomont	0.2											
Pseudanabaena galeata Bocher	0.2	0.2										
Synechococcus elongatus Nägeli		1.7	14.5	27.5	0.9	0.6	14.0	8.0	0.6	1.3		23.2
Xenococcus sp. Thuret									0.2			
Bacillariophyceae (Diatoms)												
Achnanthes exigua Grunow		1.3										
Achnanthes lanceolata ssp. dubia (Grunow) Lange-Bertalot				0.3							0.7	
Achnanthes lanceolata ssp. frequentissima Lange-Bertalot						0.4						
Achnanthes lanceolata v. frequentissima Lange-Bertalot												
Achnanthes minutissima Kützing	1.6			0.5	0.4	1.8	0.4					
Amphora montana Krasske				0.3	0.2	0.2	0.4				0.2	
Amphora pediculus (Kützing) Grunow	0.4	1.9		6.0	9.1	6.6		1.1			2.9	0.8

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Amphora veneta Kützing	0.1							0.4				
Cocconeis pediculus Ehrenberg	0.4			1.0				0.4				0.2
Cocconeis placentula v. lineata (Ehrenberg) Van Heurck	8.6	15.4	7.6	1.6	2.2	1.2	2.1	0.4			0.2	
Cocconeis placentula v. pseudolineata Geitler												
Cyclostephanos invisitatus (Hohn & Hel.) Ther., Stoerm. & Håkansson										3.2		
Cyclotella bodanica Grunow												
Cyclotella meneghiniana Kützing				0.8	1.8	0.4	1.7	4.6	2.1	2.6	1.4	
Cyclotella sp. 1 (Kützing) de Brébisson					0.2	0.8					0.7	
Cymbella affinis Kützing												
Cymbella minuta Hilse	0.2			0.3								
Cymbella silesiaca Bleisch	0.2											
Cymbella sinuata Gregory	0.2				0.2	0.2						
Cymbellonitzschia sp. Hustedt												
Diatoma vulgaris Bory												
Diploneis finnica (Ehrenberg) Cleve					0.2							
Epithemia sorex Kützing												
Epithemia sorex v. sorex Kützing						0.8						
Epithemia turgida v. westermannii (Ehrenberg) Grunow							0.2					
Fragilaria capucina Desmazières	0.2											
Fragilaria capucina v. vaucheriae (Kützing) Lange-Bertalot			0.3	0.3								
Fragilaria construens (Ehrenberg) Grunow					0.9	0.6						
Fragilaria construens f. venter (Ehrenberg) Hustedt			0.7		0.7	2.8						
Fragilaria leptostauron v. dubia (Grunow) Hustedt	0.4		0.3		0.2							
Fragilaria pinnata v. pinnata Ehrenberg	0.4											
Gomphonema augur Ehrenberg								0.4				
Gomphonema gracile Ehrenberg											0.5	

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Gomphonema olivaceum (Hornemann) de Brébisson				0.5		0.2					0.7	
Gomphonema parvulum (Kützing) Kützing	2.0	1.7	1.4	0.1	0.9	0.4	0.8		0.4		0.7	0.8
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot					0.4	1.6		0.4				
Gyrosigma scalproides (Radenhorst) Cleve			1.4									
Gyrosigma sp. Hassall	0.1											
Gyrosigma spencerii (W. Smith) Cleve											0.2	
Melosira cf. distans Agardh												
Melosira granulata (Ehrenberg) Ralfs							1.3	1.5	0.4	1.3		0.8
Melosira varians Agardh			0.3	0.3	0.2							
Navicula absoluta Hustedt												
Navicula capitata Ehrenberg												
Navicula cf gregaria Donkin								0.4				0.8
Navicula cf. lacunolaciniata Lange-Bertalot & Bonik				0.3	0.7	4.4	0.8	0.4	0.6		0.7	3.1
Navicula cryptocephala Kützing	0.8	1.1	0.3	0.8	0.4	0.4			0.6		2.2	3.1
Navicula cryptotenella Lange-Bertalot				1.0		0.2						
Navicula cuspidata (Kützing) Kützing						0.2					0.7	
Navicula decussis v. decussis Østrup					0.7	0.2						
Navicula erifuga Lange-Bertalot							0.2	0.4				
Navicula goeppertiana v. goeppertiana (Bleisch) H.L. Smith	0.2											
Navicula menisculus v. grunowii Lange-Bertalot	0.4	14.8			1.1	2.0		1.1	0.2			1.5
Navicula pupula Kützing						0.6	0.4					
Navicula rhynchocephala Kützing						0.2						
Navicula salinarum Grunow	2.4		0.3	0.3	0.7	0.8	0.4	0.4				
Navicula sp. Bory	0.4			0.5					0.2			
Navicula subminusculan Manguin								0.4			1.4	
Navicula viridula v. germainii (Wallace) Lange-Bertalot	0.2	0.4	0.3	0.3	1.3	0.8	2.5	1.9	0.8	0.6	0.7	0.2

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Nitzschia acicularis (Kützing) W. Smith	0.2							0.4	4.2			
Nitzschia constricta (Kützing) Ralfs				0.3					0.2			
Nitzschia dissipata (Kützing) Grunow				0.3								
Nitzschia fonticola Grunow				0.5	2.4	2.8	1.3	0.4	5.0	0.6	0.7	
Nitzschia fonticola v. pelagica Hustedt												
Nitzschia gracilis Hantzsch					0.4	0.2		0.8	2.7			0.8
Nitzschia inconspicua Grunow												
Nitzschia intermedia Hantzsch					0.2	0.1		0.4		0.6		
Nitzschia palea (Kützing) W. Smith				0.3	0.2	0.8	0.4		3.6	0.6	9.4	3.1
Nitzschia perminuta (Grunow) Peragallo												
Nitzschia pumila Hustedt						0.4						
Nitzschia reversa W. Smith												
Nitzschia sigmoidea (Nitzsch) W. Smith											0.7	0.2
Nitzschia sp. Hassall	0.2	0.4	0.7									
Pinnularia microstauron (Ehrenberg) Cleve												
Rhoicosphenia curvata (Kützing) Grunow	2.0	4.3	12.8	1.3	7.1	3.4	1.3	0.4				0.6
Stephanodiscus hantzschii (8-11µm) Grunow										0.6		
Stephanodiscus medius Håkansson												
Stephanodiscus niagarae Ehrenberg									0.2			
Surirella sp. Turpin												
Surirella visurgis Hustedt												
Synedra tenera W. Smith				0.3		0.2					0.2	
Synedra ulna v. ulna (Nitzsch) Lange-Bertalot				0.3								
Pyrrhophyta (Dinoflagellates)												
Gymnodinium sp. 3 Stein						0.2						
Euglenophyta												
Euglena sp. Ehrenberg												
Trachelomonas volvocina Ehrenberg					0.2							

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Miscellaneous												
Batrachospermum vagum (Roth) Agardh					0.1							